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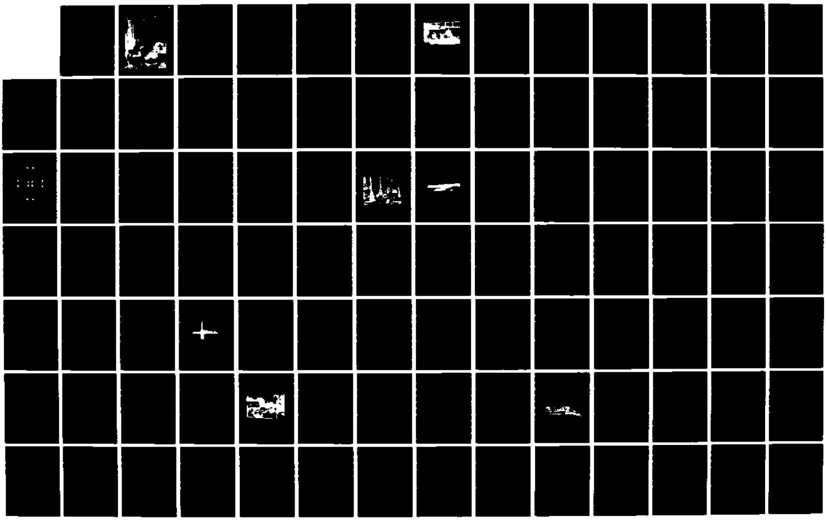

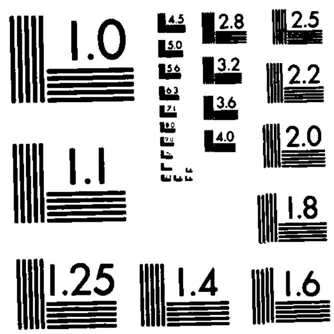

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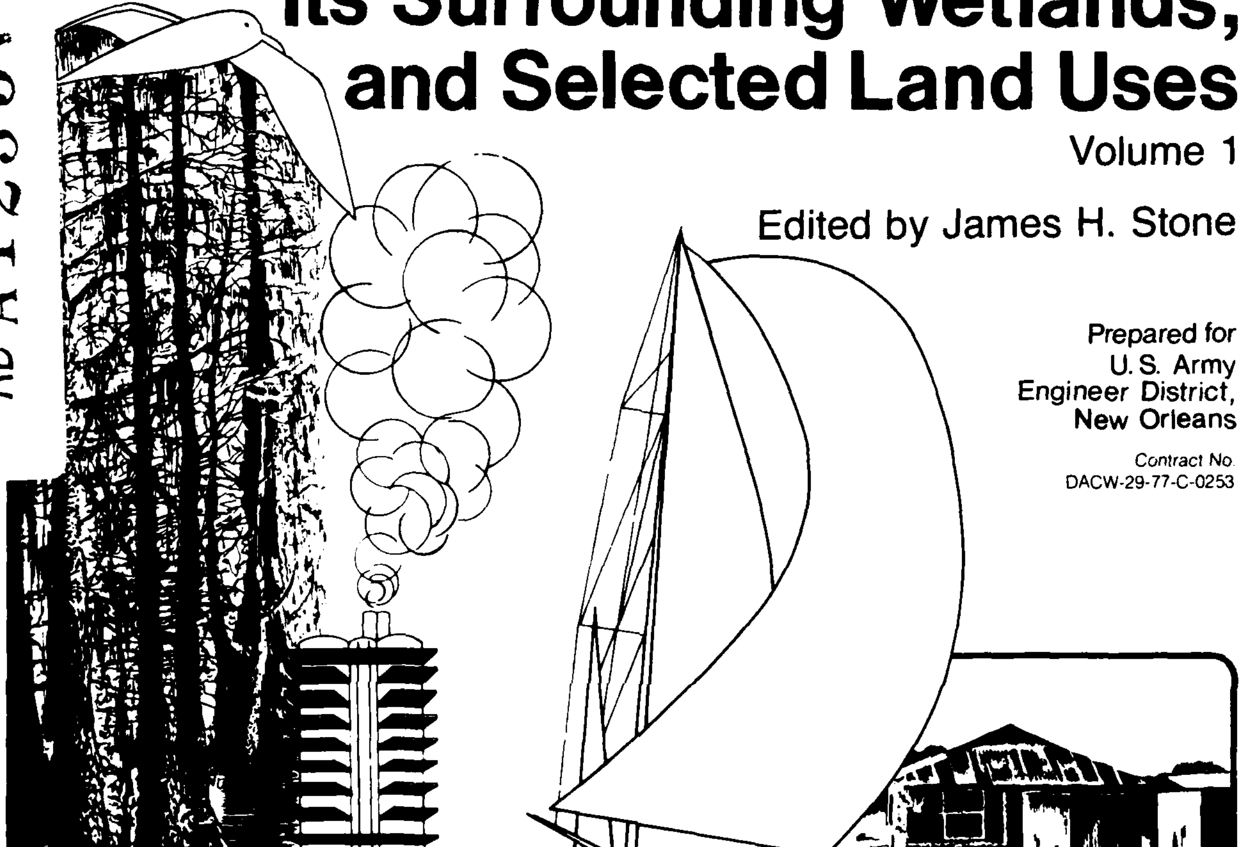
Environmental Analysis of Lake Pontchartrain, Louisiana, Its Surrounding Wetlands, and Selected Land Uses

Volume 1

Edited by James H. Stone

Prepared for
U.S. Army
Engineer District,
New Orleans

Contract No.
DACW-29-77-C-0253



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The purpose of this research was to prepare an inventory and analysis of the environmental components in Lake Pontchartrain and the wetlands surrounding the lake in order to provide an information base and to indicate salient interactions, patterns, and environmental trends to facilitate future planning. Information regarding trophic state analysis, hydrology, hydrography, chemistry, plankton, nektom, and benthic distribution within the lake were analyzed. Life history and food habitat studies were conducted on 44 fish species found in Lake Pontchartrain. In addition, preliminary study of biological transport

20. through the tidal passes within the Lake were addressed.

ENVIRONMENTAL ANALYSIS OF LAKE PONTCHARTRAIN, LOUISIANA, ITS SURROUNDING WETLANDS, AND SELECTED LAND USES

Volume 1

Edited by

James H. Stone
Coastal Ecology Laboratory
Center for Wetland Resources
Louisiana State University
Baton Rouge, Louisiana 70803

1980

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LOUISIANA STATE UNIVERSITY AND AGRICULTURAL AND MECHANICAL COLLEGE
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February 26, 1980

Col. Thomas A. Sands
District Engineer
U.S. Army Engineer District, New Orleans
P.O. Box 60267
New Orleans, LA 70160

Dear Colonel Sands:

I am pleased to submit this report documenting environmental studies of the Lake Pontchartrain, Louisiana area which were conducted during the period 1 September 1977 to 31 December 1979. The work was sponsored by the New Orleans District of the U.S. Army Corps of Engineers under Contract No. DACW 29-77-C-0253.

The investigations were directed by staff members of the Coastal Ecology Laboratory of the Center for Wetland Resources of Louisiana State University at Baton Rouge. Dr. James H. Stone served as project manager and principal investigator under the general supervision of Dr. Suzanne E. Bayley, Director, Coastal Ecology Laboratory. Associate project leaders were Drs. John W. Day, Leonard M. Bahr, Jr., and R. Eugene Turner.

The report examines Lake Pontchartrain and its environs from the standpoint of selected ecological components and processes, useful ecologic models and simulations, and effects of natural and cultural events on environmental quality.

A primary objective of the LSU Center for Wetland Resources is effective utilization of university capabilities in addressing practical coastal and floodplain problems. As the New Orleans District Corps of Engineers plays a vital role in the conservation and development of Louisiana wetlands, it has been particularly appropriate and gratifying to work with your office in the conduct of this program.

Sincerely,

Jack R. Van Lopik

Jack R. Van Lopik
Dean
Center for Wetland Resources

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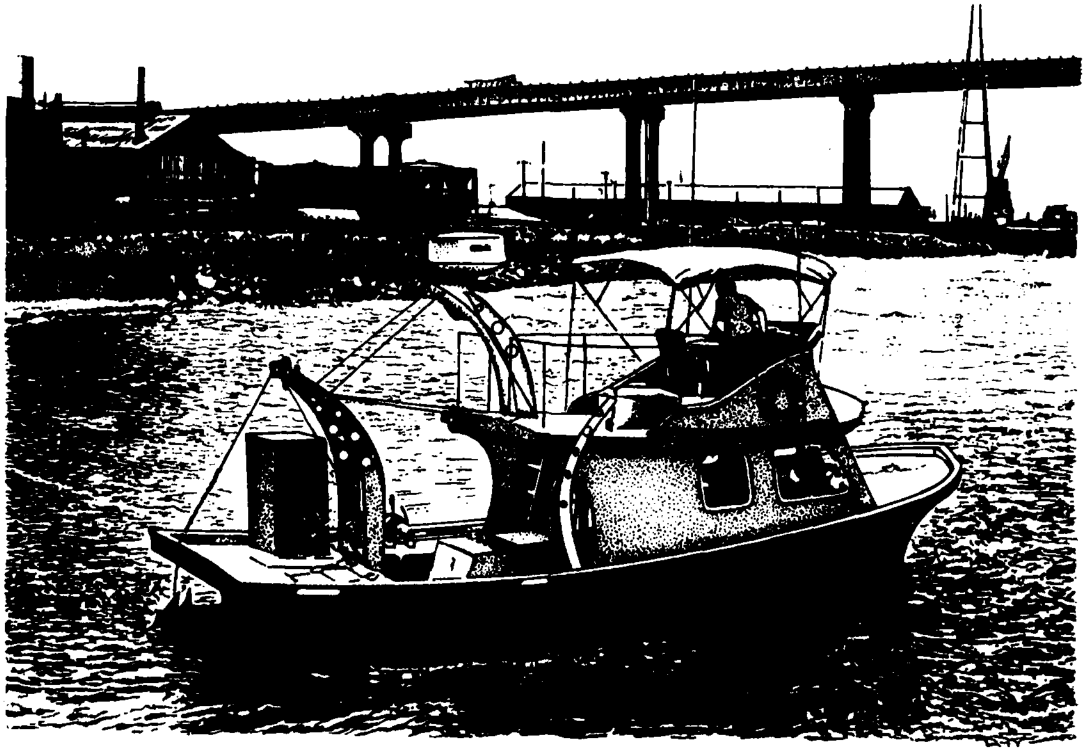

LSU work boat Wampus Cat

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PREFACE

Purpose

This project was conducted for the Planning Division, Department of the Army, New Orleans District, Corps of Engineers (COE), P. O. Box 60267, New Orleans, Louisiana 70160, under Contract No. DACW29-77-C-0253. The purpose of this research was to prepare an inventory and analysis of the environmental components in Lake Pontchartrain and the wetlands surrounding the lake in order to provide an information base and to indicate salient interactions, patterns, and environmental trends to facilitate future planning.

Chief of the Planning Division of the New Orleans COE District during the study was James F. Roy. Contracting Officer Representatives of the COE were William E. Shell, Jr., John C. Weber, Frank J. Cali, Sue R. Hawes, and Larry M. Hartzog.

Organization

Our research efforts were divided among various teams; each of these is given below with their members.

Team/Worker	Members
• Project Supervision	James H. Stone, John W. Day, Jr., Leonard M. Bahr, Jr., and R. Eugene Turner
• Hydrology	Erick M. Swenson
• Vegetation and Land Use Mapping	R. Eugene Turner, Rezneat M. Darnell, and Judith R. Bond

• Nutrient and Water Chemistry	Ronald K. Stoessell, Patricia A. Byrne, Annie M. Prior, and Judith R. Bond
• Primary Production and Structure	David D. Dow and R. Eugene Turner
• Plankton	Lawrence L. Cook, Edward C. Theriot, Nancy A. Drummond, Diane M. Lindstedt, and James H. Stone
• Benthos	Leonard M. Bahr, Jr., Jean P. Sikora, Walter B. Sikora, and Nan D. Walker
• Nekton	Bruce A. Thompson, Marion T. Fannaly, Steven J. Levine, J. Stephen Verret, Robert C. Cashner,* and Olivia House*
• Nekton Food Habits	Steven J. Levine, Bruce A. Thompson, Marion T. Fannaly, and J. Stephen Verret
• Macroplankton in Tidal Passes	Marion T. Fannaly, Bruce A. Thompson, Steven J. Levine, and J. Stephen Verret
• Anchovy	J. Stephen Verret, Bruce A. Thompson, Steven J. Levine, and Marion T. Fannaly
• Preliminary Survey of Higher Vertebrates	James J. Hebrard and James H. Stone
• Consultants	Rezneat M. Darnell,* Richard W. Heard,* Robert C. Cashner,* and Olivia House*
• Graduate Students — Modeling	Robert E. Hinchee and Linda A. Deegan
Grassbeds	Diane L. Steller and Richard L. Miller
Benthos	Glen W. Cramer
Plankton	Nancy A. Drummond
Food Web	Keith W. Higgins
• Modeling and Project Evaluation	James H. Stone, B. T. Gael, Linda A. Deegan, Robert E. Hinchee, John W. Day, Jr., Leonard M. Bahr, Jr., and R. E. Turner

---

*R. C. Cashner is affiliated with the Department of Biology, University of New Orleans; O. House is affiliated with the Department of Biology, St. Mary's Dominican College, New Orleans; R. M. Darnell is affiliated with the Department of Oceanography, Texas A&M University, College Station, Texas; R. W. Heard is affiliated with Richard W. Heard and Associates, Marine Environmental Consultants, Ocean Springs, Mississippi.

Support effort was provided by the following personnel:

• Logistical	Rodney D. Adams, Edwin M. Bishop, Paul Rabalais, Glen E. Ehrett, and J. Kenneth Kuzenski
• Boat	Michael J. Haight and Russell J. Wilson (Rental from Toula Enterprises, Inc.)
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• Technical Editing	Joy D. Bagur

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*All contributors are staff members of the Center for Wetland Resources, Louisiana State University, Baton Rouge, LA 70803, with the exception of R. M. Darnell; Dr. Darnell is affiliated with Texas A&M University, College Station, Texas 77843.

EXECUTIVE SUMMARY: AN EMERGING VIEW OF THE LAKE PONTCHARTRAIN ECOSYSTEM

by

James H. Stone
John W. Day, Jr.
Leonard M. Bahr, Jr.
and
R. Eugene Turner

Lake Pontchartrain is a shallow, slightly brackish estuary that is located in the deltaic plain of the Mississippi River in southeastern Louisiana. The 1631 km^2 (629 mi^2) lake is fringed by 1603 km^2 (619 mi^2) of forest swamp and by 808 km^2 (312 mi^2) of fresh to brackish marsh. Greater New Orleans, with its approximately 1.2 million people, occupies about one half of the south shore. Lake Pontchartrain is an urban lake, and it is the focus of this report.

During 1978-1979, a year-long study was made by Louisiana State University of selected ecological components and processes of Lake Pontchartrain and its surrounding wetlands and of selected land uses in its drainage basin or watershed. This research was based on the premise that many of the important ecological events occurring within the lake are probably directly linked to actions happening elsewhere in the basin and hence outside the lake. Our data confirm this premise.

SALIENT FEATURES

The two most salient features of our studies are: (1) average turbidity (the amount of sediment suspended in the water) has increased by about 50 percent over the last 25 years; and (2) nutrients (phosphorus and nitrogen) are significantly higher in areas fringing and surrounding

the lake such as in Lake Maurepas, in the marshes, and along the southeast shoreline just off New Orleans. We estimate that total phosphorus loading to Lake Pontchartrain has increased by about 70 percent since the 1950's.

An obvious question is: What are the effects of increased turbidity and nutrient loading on the Lake Pontchartrain ecosystem? We know part of the answer. For example, we know that turbidity reduces the amount of plant material produced in the water of the lake. This plant material is critical to the existence of many organisms, including some fish. For example, we estimate that fish production in Lake Pontchartrain has decreased by about six percent between 1953 and 1978 as a result of increased water turbidity.

In addition, we know that nutrients increase the amount of plant material in the water; our plankton data confirm that this has happened off Pass Manchac, in the surrounding marshes, and near the south shore next to New Orleans.

These two facts would appear to offset one another, but the interaction between suspended sediments and nutrients is definitely not that simple, and many details remain unknown at this time. We do know, however, that the excessive nutrients are producing large amounts of plant material, such as Anabaena spp. and Oscillatoria spp.; these forms are known to indicate eutrophication and to cause changes in the species composition of the food web. Also, we intuitively feel that the nutrients coming into the lake from Lake Maurepas, from New Orleans, and from the bayous and drainage canals in surrounding marshes are probably being taken up by the suspended material in the water column of the lake. Their ultimate fate is unknown but their probable impact is a reduction of plant material

since, if absorbed by sediments, they would not be available for photosynthesis. In addition, as these sediments settle they can smother bottom forms, and this would in turn eventually reduce fish production and their commercial harvest.

Another obvious question is, What is causing the increased turbidity and nutrient concentrations in Lake Pontchartrain? Some of turbidity in the lake is caused by natural forces, i.e., the wind. We estimate that winds blowing over Lake Pontchartrain are sufficient to stir and mix bottom sediments throughout the water column about 15 percent of the time. But we also estimate that some of man's activities, such as shell dredging, can produce a significant amount of suspended materials in the water column that might affect up to one quarter of the lake at any one time. Nutrients are entering Lake Pontchartrain from several sources. Near Pass Manchac, the nutrients come mostly from the Amite-Comite drainage area (near and about the Baton Rouge area).

We believe that estuarine ecosystems such as Lake Pontchartrain are more fruitfully considered at the level of the coastal drainage basin or watershed (Fig. 1). Therefore, we consider the Lake Pontchartrain ecosystem to include bodies of open waters, associated wetlands, upland forests, agricultural lands, rivers, the associated natural processes, and human activities operating within its drainage basin and under its climatic influences. For simplification, it is possible to consider the Lake Pontchartrain estuarine basin as four linked components, each representing a different (but sometimes overlapping) aspect of structure and a different set of processes. The four components are shown in Figure 2: (A) "Hydrology" is water storage and flow throughout the basin; (B) "Natural Resources" deals with the structure and function of

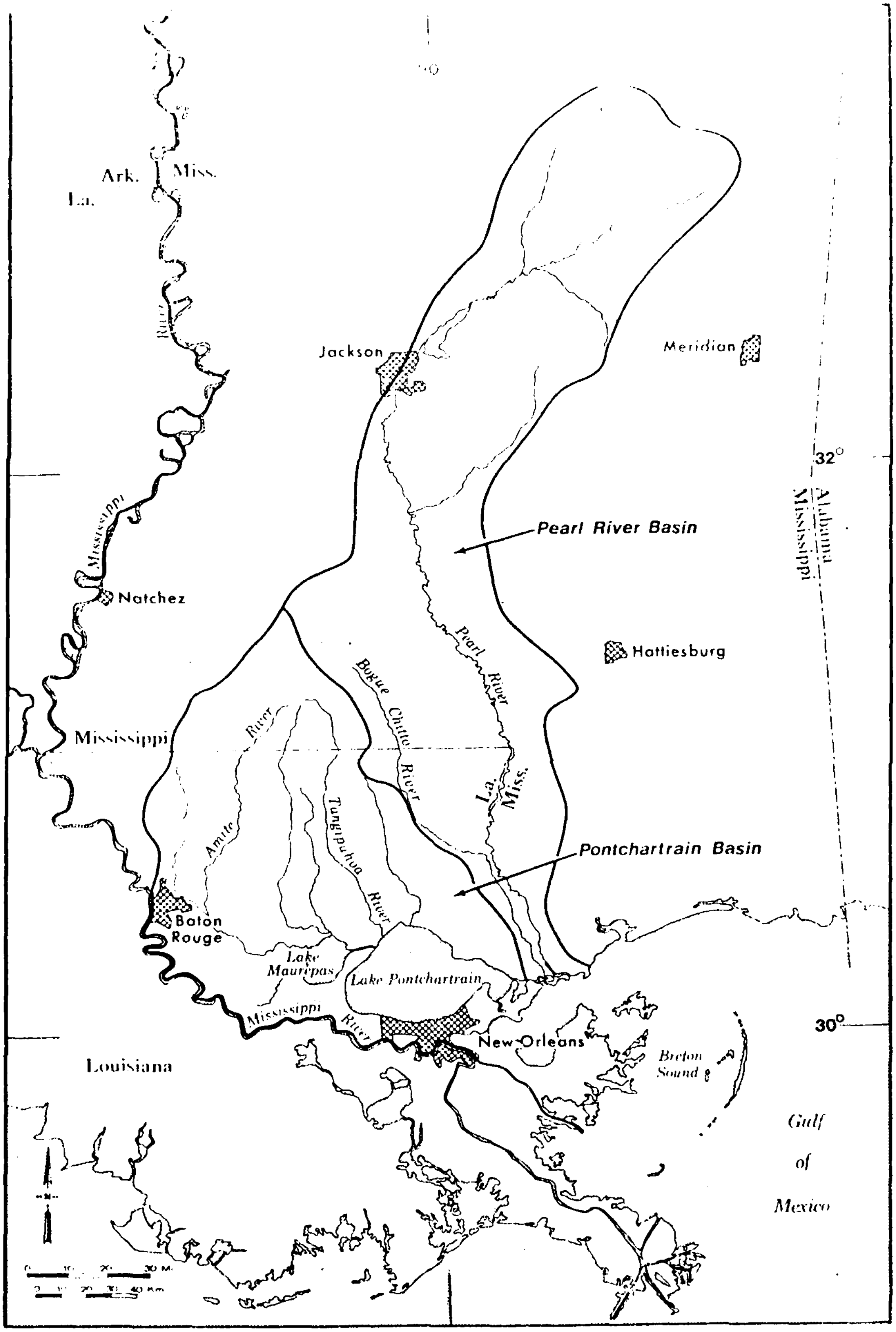


Figure 1. A general area map of the Lake Pontchartrain Basin showing the major rivers, cities, and the adjoining Pearl River Basin.

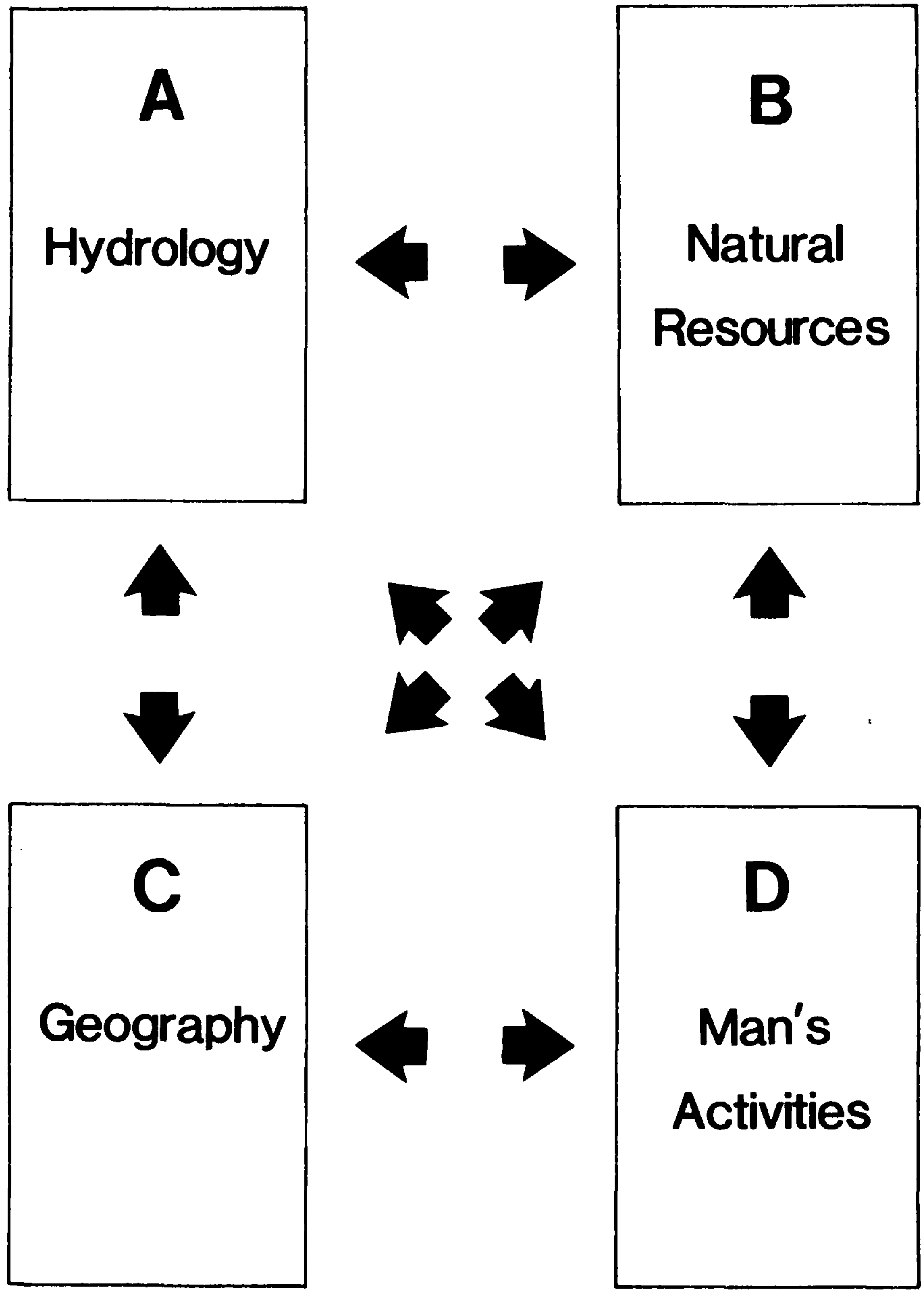


Figure 2. Conceptual view of the Lake Pontchartrain ecosystem (modified from Bahr in Stone et al. 1980). Chapters 3,4,5, and 19 deal with A. Hydrology. Chapters 7,8,9,10,11,12,13,14,15,16, and 17 deal with B. Natural Resources. Chapters 9,10, and 18 deal with Geography (C). Chapters 1,2, and 6 provide a context for the data of the other chapters

the basin or its capacity to support all living forms (such as wildlife and fisheries) and to perform work services for man; (C) "Geography" or the physiography of the basin is the structure and accretion of natural lands such as forests, swamps, marshes, and grassbeds; and (D) "Man's Activities" operating within the basin.

Our 1978-1979 research efforts in Lake Pontchartrain concentrated on the (A) hydrology, (B) natural resources, and, to a lesser extent, on (C) geography. Component (D), man's activities, were not studied per se under this contract, but we have other ongoing efforts dealing with them; consequently, we repeatedly ask during our study what, how, when, and why man's activities affect each of the other three components or their subparts. Indeed, we believe that man's activities are one of the prime motivations for initiating this study.

Under each of the components of Figure 2 we have listed the chapters of our report that deal with selected parts and processes of that particular component. Chapters 1, 2, and 6 are more synthetic in that they provide a context and/or meaning for the data of the other chapters. Specific findings are summarized below under the three major compnents (i.e., A, B, and C), and followed by a general overview or a summary of chapters 1, 2, and 6.

A. Hydrology
(Chapters 3, 4, 5, and 19)

The circulation of Lake Pontchartrain is dominated by an easterly wind with either a north or south component, depending on the season. Wind speeds greater than 15 mph, which occur about 15 percent of the time, cause bottom sediments to become stirred and mixed throughout the water column and often impart a brownish color to the water. Tidal

movements and water heights are amplified by the action of wind and rain in the Pontchartrain basin. For example, ebb tides in Pass Manchac and in each of the three tidal passes can continue unabated for several days. The lake is a well-mixed system; it shows little vertical stratification and a weak salinity gradient from a low of zero ppt in the west to a high of about nine ppt in the east during 1978. The general circulation pattern for both flood and ebb tides shows a littoral drift to the west along both the south and north shores and a return current by way of a broad band of water running approximately from the northwest to the southeast. Counter currents and eddies exist, however, in this area. Cells of waters, formed either by convergence or divergence, may persist near Pass Manchac and near the lakefront of New Orleans. These waters do not seem to mix as rapidly as those in other locales in the lake; they may persist for as long as 10 days. The discharge of waters through the Bonnet Carre Floodway markedly change the general circulation pattern. This water moves easterly near the south shore and mid lake and occupies one-half to two-thirds of the entire lake. Runoff from the Baton Rouge area also affects the hydrology of the basin and may increase the flushing time of Lake Maurepas by 30 percent, which in turn may affect between 2 to 10 percent of Lake Pontchartrain waters.

The Rigolets accounts for 44 percent of water transport in and out of the lake; Chef Menteur Pass, Inner Harbor Navigation Canal (IHNC), and Pass Manchac account for 32, 6, and 15 percent, respectively. Inflow of salt through the IHNC is twice as great as outflow, which suggests local accumulation for probably a short but unknown period of time. Annually, input by rivers account for about five percent of the

total volume of the lake and most of the river volume (80%) is from the Amite-Comite and Tangipahoa Rivers.

B. Natural Resources
(Chapters 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17)

Plankton numbers, biomass, and productivity were higher near the lakefront of New Orleans, especially off the Bonnabel Discharge Canal and the Inner Harbor Navigation Canal, near the outfalls of Pass Manchac and off the Tangipahoa and Tchefuncte Rivers. Phytoplankton were significantly more abundant (statistically) in the marshes fringing Lake Pontchartrain. Plankton kinds and number were also found to be about the same throughout the rest of the lake, which partially verifies that the lake is a well-mixed system. Plankton data corroborate the findings of the hydrologic and nutrient studies; phytoplankton were significantly more abundant in areas of higher concentration of nutrients but almost all species were found throughout the lake. Turbid waters caused by strong winds during late winter tend to inhibit photosynthesis. During spring and early summer, waters are less turbid, and the high plankton production is probably related to the concentration of phosphorous that was at a maximum then. During mid-summer conditions, plankton become less active, possibly because nitrogen was found to be at a minimum at that time. Plankton from Lake Pontchartrain are stimulated by substances in the waters of Lake Maurepas but are inhibited by substances in the waters of Lake Borgne.

Marsh grasses fringing Lake Pontchartrain are similar in structure and production to other brackish marshes in Louisiana. However, the impounded marsh in the New Orleans East area is shifting from brackish towards distinctly fresh marsh. The forest swamp in St. Charles Parish appears

to be healthy and productive, but production and litterfall are significantly lower near Blind River. Causal factors appear to be continual flooding of this area and insect grazing. Forests in the Lake Pontchartrain Basin have been reduced by 40 percent, and the remaining forest is less dense; indeed, the forest swamps fringing the northwestern side of Lake Pontchartrain are almost devoid of trees and are becoming (functionally) marshes. This is particularly important to the higher vertebrates because the forest swamp is their principal habitat. The submerged grassbed habitat, which is located mostly along the north shore of Lake Pontchartrain, shows a 25 percent reduction over the last 25 years in the shoreline distribution of two of its dominant species, *Ruppia maritima* and *Vallisneria americana*. This habitat is especially critical for many invertebrate and fish species; its area (about 2000 acres) and its general health should be monitored closely.

The macrobenthos of the lake is sparse in terms of numbers and species. However, initial biomass estimates of the total benthos (which include meiobenthos) are high and may suggest that the benthos are not suitable food for fishes or are not used by them. There are other possibilities, such as that the water transparency is insufficient to allow feeding on the benthos by the fish or that the bottom sediments are not stable enough to maintain a viable benthic community. These are critical questions that need to be answered because our studies on the food habits of the fishes of Lake Pontchartrain indicate that the fishes use two types of food webs: a benthic food web, and a planktonic food web.

Overall, the nekton of Lake Pontchartrain appear to be relatively healthy and seem to use Lake Pontchartrain environs primarily as a

nursery. Preliminary data suggest that demersal fish catch per effort is considerably less than in the 1950's, which could indicate that there may be some problems in the transfer of energy between the benthos and the nekton. In addition, commercial fish harvest data suggest a slight reduction in the number of crabs, shrimp, and catfishes within Lake Pontchartrain.

C. Geography
(Chapters 9, 10, and 18)

Man's use of land within the Lake Pontchartrain Basin is increasing the rate and frequency of runoff waters and the amount of nutrients and sediments reaching the lake. They, in turn, may be causing a reduction in the lake's average salinity. The shoreline of Lake Pontchartrain is eroding at a rate of about 15 ha/yr (37.1 acres per year); the shoreline of Lake Maurepas is eroding at 0.5 ha/yr (1.2 acres per year). This difference in erosion rates may indicate that more of the basin's sediments are settling in Lake Maurepas than in Lake Pontchartrain, but Lake Pontchartrain is about five times larger than Lake Maurepas, and a direct comparison may not be possible.

D. Overview
(Chapters 1, 2, and 6)

Nutrients are significantly higher in the areas fringing Lake Pontchartrain than in the center of the lake. For example, nutrient loads are greater in the bayous and drainage canals of the marshes, off New Orleans, and near Pass Manchac. Trophic state analyses confirm these data. It appears that the nutrients are being taken up in part by the phytoplankton and, perhaps, in part by the suspended material in the lake proper.

Preliminary computer simulations of the Lake Pontchartrain ecosystem estimate that fish production has decreased by about 6% during the last 25 years because of an increase of turbidity. Wetland destruction since 1900 (about 67%), however, has probably had a greater adverse effect on the Lake Pontchartrain ecosystem.

The most important environmental trends in the Lake Pontchartrain ecosystem are: (1) a continuing loss of surrounding wetlands, (2) increasing nutrient loading into the lake, and (3) a progressive increase in the lake's turbidity.

Forest swamp in St. Charles Parish

Fort Macomb and boat marina

HIGHLIGHTS AND CONCLUSIONS

by

James H. Stone

CHAPTER 1. PRELIMINARY MODELING OF LAKE PONTCHARTRAIN ECOSYSTEM BY COMPUTER SIMULATIONS

- Lake Pontchartrain can be considered as a six compartment or trophic level model driven by sunlight and nutrients; the six levels are submerged grassbeds, phytoplankton, zooplankton, benthos, nekton, and detrital microbes. This simple model contains 22 types of interactions among the six compartments. (Simulation results are presented in the following four highlights.)
- Fish production in the Lake Pontchartrain ecosystem has been reduced by 49 percent since 1900 because of the loss of wetlands.
- If the grassbeds along the north shore of Lake Pontchartrain were eliminated, fish production within the basin would decline by an additional 26 percent.
- The nursery value of the grassbeds and marshes is three and four times, respectively, greater than their potential as a food source.
- An increase of turbidity between 1953 and 1978 caused a reduction in the production of phytoplankton, zooplankton, benthos, and fish by 38, 6, 5, and 6 percent, respectively.

CHAPTER 2. A TROPHIC STATE ANALYSIS OF LAKE PONTCHARTRAIN, LOUISIANA, AND SURROUNDING WETLAND TRIBUTARIES

- A Trophic State Index (TSI) developed for Coastal Louisiana is based on four variables: total organic nitrogen (TON), total phosphorus (TP), Secchi disc depth (SD), and chlorophyll a (chloro a).
- Preliminary analyses suggest that Secchi disc depth (a measure of suspended material in the water or turbidity) and total phosphorus (a nutrient) are the most important variables for assessing the trophic state in Barataria Basin waterbodies.
- The marshes fringing Lake Pontchartrain are hypereutrophic, which means they have a high concentrations of nutrients and phytoplankton.
- Lake Pontchartrain is classified by the Louisiana TSI as meso-to-oligotrophic, which implies low productivity and low nutrient enrichment within the lake itself.
- High nutrient concentrations reaching the lake may be removed by means of both flocculation and saline waters.

CHAPTER 3. COMPUTATION OF DRIFT PATTERNS IN LAKE PONTCHARTRAIN, LOUISIANA

- Under normal conditions, wind is the most important cause of water motion in the lake; river and tidal inputs are not usually significant.
- During spring (April and May) there is a littoral drift toward the west along both the north and south shore, with a return current mid lake.
- Summer conditions, with gentle southeast winds, produce large gyrals in the center of the lake and a westerly or windward drift along both the north and south shores.

- Fall to winter conditions, with gentle northeast winds, produce gyrals in the center of the lake and a longshore drift toward the west.
- Extreme events, such as discharges from the Bonnet Carre Floodway or strong winds, can change the normal circulation markedly by suppressing the near shore and the wind-driven currents. The result is that most of the water moves directly through the center of the lake.
- Water discharges during summer along the lakefront of New Orleans probably tend to move very slowly to the west and do not disperse or purge themselves very quickly.

CHAPTER 4. GENERAL HYDROGRAPHY OF LAKE PONTCHARTRAIN, LOUISIANA

- Current speeds in the lake average 12 to 14 cm/sec. The lake does not show a strong two-layered (or stratified) system in terms of currents although two-layered flow is evident near the Inner Harbor Navigation Canal.
- Vertical profiles of conductivity (salinity) generally show a slight increase from lake surface to bottom of 1 to 2 mmhos/cm; water temperatures show a corresponding decrease of 1 to 2° C.
- Tides are diurnal, but winds can markedly change their cycle. The Lake appears to have a forced tidal oscillation, with the water level over the entire lake rising and falling as a unit.
- Water level in Lake Pontchartrain is controlled by tides and easterly winds. Wave heights are directly related to winds.
- During 1978, water temperatures during winter were lower than average, above average during spring and summer, and above average in the fall. Rainfall was slightly below average during all seasons,

but river flows were higher than normal during winter, somewhat low during spring, normal during summer, and below average during fall. Lake salinity. Lake salinity followed the normal pattern, with a minimum in the spring and a fall peak.

- The eastern half of the lake is influenced more by tidal factors than the western half; the western half shows more freshwater (or river input) effects. The "division" line runs approximately between Green Point and Walker Canal in the St. Charles marsh.
- Wind speeds of 15 to 38 mph and greater cause the bottom sediments to become mixed throughout the water column, and it is estimated that this mixing occurs about 15% of the time.
- The wetlands surrounding Lake Pontchartrain are generally flooded during spring (May) and fall (September), and flooding coincides with high water levels in the lake. Marshes are flooded about 50% of the time, primarily by storms.
- Water discharges from the Bonnet Carre Floodway move easterly close to the south shore and do not seem to affect the north shore. This water can affect up to one-half to two-thirds of the lake's total volume. Over a 60-day period, these water discharges can replace the total volume of the lake, which is six times faster than average total streamflow would replace the total volume.

CHAPTER 5. GENERAL HYDROGRAPHY OF THE TIDAL PASSES OF LAKE PONTCHARTRAIN, LOUISIANA

- The lengths of The Rigolets, Chef Menteur Pass, and Inner Harbor Navigation Canal tidal passes are 14.5, 11.3, and 30 km, respectively. Their respective cross-sectional areas are 7500, 2422, and 1125 m^2.

- The vertical structures of currents are similar in each of the three tidal passes; they are usually homogeneous and not two layered, except at times in the Inner Harbor Navigation Canal. There is no pronounced vertical stratification in The Rigolets and the Chef Menteur passes; however, a salt wedge is often present in the Inner Harbor Navigation Canal.
- Wind in the tidal passes can significantly extend a flood or ebb tide.
- Transport of biological and chemical species should be more homogeneous in The Rigolets and the Chef Menteur Pass and more constrained to the bottom or salt wedge in the Inner Harbor Navigation Canal.
- Water transported in and out of Lake Pontchartrain is mainly via The Rigolets (∿44 percent) and the Chef Menteur Pass (32 percent); the Inner Harvor Navigation Canal and Pass Manchac account for lesser amounts, i.e., 6 and 15 percent, respectively.
- It takes about 100 days for all the water of Lake Pontchartrain to flush out into the Gulf of Mexico.
- The tidal passes are about four times more important than rivers in determining salt and water content of Lake Pontchartrain. Rivers supply about 5 percent of the total volume of the lake, and the Amite-Comite and Tangipahoa Rivers supply 80 percent of this.
- The Rigolets and Chef Menteur Pass each supply about 40 percent of the salt transported into the lake; the Inner Harbor Navigation Canal accounts for about 20 percent.
- Tidal energy through The Rigolets is about equal to the energy flow through the Chef Menteur Pass and, in turn, the tidal energy through the Inner Harbor Navigational Canal is negligible because of the small volume flow through it.

- Tides predominate in Lake Pontchartrain when winds range in speed between 1 to 2 m/sec; they are about equal when winds range between 3 to 4 m/sec; and winds predominate when greater than 4 m/sec.
- Currents within the tidal passes correlate well with a change in electric potential as measured by electrodes. The electrode technique offers a relatively inexpensive way to monitor currents continuously.

CHAPTER 6. NUTRIENT AND CARBON GEOCHEMISTRY IN LAKE PONTCHARTRAIN, LOUISIANA

- Nutrient and carbon concentrations show seasonal trends within Lake Pontchartrain.
- PO_4^{3-}, dissolved P, and Si concentrations were usually high in spring, low in summer, and they increased in the fall.
- $NH_3 + NH_4^+$ and $NO_2^- + NO_3^-$ levels were usually high in spring, low in summer, and they remained low in the fall.
- Organic N fractions and undissolved P content did not show consistent lake-wide trends.
- The highest values of PO_4^{3-} and dissolved P usually occurred doing the south side of the lake.
- Inorganic C concentrations increased from west to east and southeast across Lake Pontchartrain.
- Dissolved organic C levels were high in the spring, low in the summer, and increased in the fall.
- Undissolved organic C levels were high in spring and nearly non-detectable in the summer and fall.
- Nutrient concentrations in Lake Pontchartrain rank between high values of Barataria Bay estuary and average (nutrient depleted) sea water.

CHAPTER 7. STRUCTURE AND FUNCTION OF THE PHYTOPLANKTON COMMUNITY IN IN LAKE PONTCHARTRAIN, LOUISIANA

- Water transparency is generally lower (the water is more turbid) during winter and spring than during summer and fall.
- Near Pass Manchac the waters are usually more turbid than at other lake locations.
- Water turbidity in Lake Pontchartrain may be caused by weather fronts and their wind systems.
- Fluorescence, chlorophyll _a_, and primary production are usually highest near the southeast shoreline near New Orleans and its suburbs.
- Water plumes near the New Orleans shoreline appear to move predominately toward the east.
- High plankton biomass was often found just off the entrances of the Tchefuncte and Tangipahoa Rivers. These blooms were often dominated by the blue-green alga _Anabaena_ spp. In addition, dense blue-green algal blooms were also found off Pass Manchac and in Lake Maurepas.
- The most active (physiologically) phytoplankton populations were often off Pass Manchac.
- The waters of the western half of Lake Pontchartrain are generally more turbid but contain more active phytoplankters.
- Phytoplankton populations of Lake Pontchartrain appear to be light-limited during winter, nitrogen-limited during mid-summer, and phosphorus-limited during spring and early summer.
- Spatial and temporal variations of phytoplankton population in Lake Pontchartrain are often pronounced. These variations may be artifacts of sampling or indications of well-mixed waters.

- Inorganic nitrogen in Lake Pontchartrain comes primarily from Lake Maurepas. Lake Maurepas receives its nitrogen from the Amite and Comite Rivers. Other nitrogen sources for Lake Pontchartrain are the drainage canals of Metropolitan New Orleans.
- Inorganic nitrogen in Lake Pontchartrain does not exhibit the fluctuations or high concentrations found in Lake Maureaps. Lake sediments or biota may dampen these effects.
- Phytoplankton taken from outside of Lake Pontchartrain are stimulated by being mixed with water from the lake. Organisms from Lake Pontchartrain are inhibited by being mixed with water from outside the lake.
- Nitrogen appears to be the major growth-limiting nutrient for phytoplankton of Lake Pontchartrain.
- Inorganic nitrogen for Lake Pontchartrain appears to come mainly by way of Pass Manchac, Lake Maurepas, the Amite River, and the drainage canals of Metropolitan New Orleans.
- Inorganic nitrogen concentrations in Lake Maurepas show other fluctations than those of Pass Manchac (and thus Lake Pontchartrain), which suggests something is damping the fluctuations of nitrogen in Lake Pontchartrain.

CHAPTER 8. THE DISTRIBUTION AND ABUNDANCE OF PLANKTON OF LAKE PONTCHARTRAIN, LOUISIANA, 1978

- Phytoplankters are significantly more abundant in the marshes surrounding Lake Pontchartrain than in the lake itself.
- Two recurrent groups or associations of phytoplankton taxa prevail in the Lake Pontchartrain area. Both groups are characterized by freshwater and euryhaline members.

- Group I is made up of eight taxa and one associate. It occurred only during the summer and fall months and was found more in the lake (48%) than in the marshes (30%).
- Recurrent Group II is made up of three taxa and two associates. It occurred during all months of the year and was found more in the marshes (53%) than in the lake (28%).
- Phytoplankters are taxonomically more diverse in the marshes than in the lake during spring and summer. During fall and winter, the number of taxa are almost the same in the two areas.
- Microzooplankton are taxonomically more diverse in the marshes than in the Lake Pontchartrain proper.
- Four recurrent groups or associations of microzooplankton taxa prevail in the environs of Lake Pontchartrain.
- Group I is made up of seven taxa and was found mainly (91% of the time) during summer months and at lake stations (51%). It is a fresh to brackish water association.
- Groups II and III are each made up of two taxa. Group II was found during all months of the year and equally in the lake and in the marshes. Group III was found only during winter and early spring and equally in the lake and in the marshes. Both groups are fresh to brackish water associations.
- Group IV is made up of two taxa. It was found only rarely, and the taxa are freshwater associations.
- Three recurrent groups or associations of macrozooplankton prevail in the environs of Lake Pontchartrain.
- Group I, Argulus sp. and Crab Zoea (mud crab), occurred predominately during summer and mostly (56%) within the lake proper. It is a brackish water association.

- Group II, Acartia tonsa (adults and juveniles) and Copepoda nauplii, occurred during all months of the year and mostly at lake stations. Both are brackish water associations.
- Group III, Cladocera and Mesocyclops edax, occurred mostly during spring and summer at marsh stations. It is a freshwater association.

CHAPTER 9. PRODUCTIVITY OF THE SWAMPS AND MARSHES SURROUNDING LAKE PONTCHARTRAIN, LOUISIANA

- Detritus formation in the impounded marsh of New Orleans East is higher than in Goose Point marsh or Irish Bayou marsh; it is about the same as in the Walker Canal marsh.
- Live and dead marsh grass (Spartina patens) is less dense in the impounded marsh of New Orleans East than in other marsh areas surrounding Lake Pontchartrain.
- Net production of marsh grass is generally higher in Walker Canal than in other marsh areas surrounding Lake Pontchartrain.
- Spartina patens is the dominant macrophyte in the brackish marshes surrounding Lake Pontchartrain (namely, in Tchefuncte, Green Point, Cane Bayou, Goose Point, and Bayou Bonfouca marshes). Fresher marshes (such as Tchefuncte Canal and Bayou Powell) are dominated by Sagittaria lancifolia. Big Point marsh is dominated by S. patens and Scirpus olneyi. Brackish marshes exhibited a higher biomass and lower species diversity than freshwater marshes.
- Nutrient levels are generally higher in the water of the impounded marsh of New Orleans East and in the St. Charles marsh (near Walker Canal) than in other marsh areas surrounding Lake Pontchartrain.

- Swamp forests of St. Charles marsh are dominated by baldcypress and Drummond red maple. Swamp forests of Blind River are dominated by water tupelo, Drummond red maple, ash, and baldcypress.
- The swamp forest of the St. Charles marsh is relatively healthy and productive (1097 g dry $wt \cdot m^{-2} \cdot yr^{-1}$) compared to the swamp forest in the Blind River (621 g dry $wt \cdot m^{-2} \cdot yr^{-1}$). This difference could be caused by earlier intensive logging, heavy insect grazing, and perhaps more importantly by continual flooding.
- The New Orleans East marsh is changing from its original brackish character into a fresh marsh as a result of its impoundment.
- Litter-fall in the swamp forest of Blind River is probably being significantly reduced because of insect grazing.

CHAPTER 10. CHANGES IN THE SUBMERGED MACROPHYTES OF LAKE PONTCHARTRAIN (LOUISIANA): 1954-1973

- Two species of submerged grasses dominate the grassbeds of the north and south shores of Lake Pontchartrain: *Ruppia maritima* and *Vallisneria americana*. *Najas guadalupensis* is now present in areas where it was not found in 1954. *Potamogeton perfoliatus* was abundant in 1973 but was not found in 1954.
- Urban areas have increased three times and eight times on the south and north shore, respectively, between 1954 to 1974, especially along those shore areas where the submerged grassbeds have declined. Causal factors may be eutrophication (from agricultural and urban discharges), saltwater intrusion (via the Inner Harbor Navigation Canal), and selected toxins (via chlorination of discharge water).
- There was approximately a 25 percent decline in the shoreline distribution of *R. maritima* and *V. americana* between 1954 and 1973.

- Most of the decline of these two macrophytes occurred near New Orleans (along the south shore) and near The Rigolets. Rising salinities may have caused this decline because salinities were higher during 1973 than in 1954.
- Other factors that could possibly reduce the macrophytes include urban development and discharges and increased turbidity, particularly since a similar decline of macrophytes has also occurred near Madisonville and Mandeville.

CHAPTER 11. MACROBENTHIC SURVEY OF LAKE PONTCHARTRAIN, LOUISIANA, 1978

- Water column salinities in Lake Pontchartrain suggest a western low salinity zone and an eastern higher salinity zone; the former comprises 60 percent and the latter, 40 percent of the lake area.
- Sediment analyses reveal at least seven sediment types in the lake but silty clay dominates the other types.
- Organic carbon in the sediments of Lake Pontchartrain are somewhat lower (∿ 1% carbon by weight) than other estuaries, such as in South Carolina and Georgia.
- The macrobenthos of Lake Pontchartrain is relatively depauperate in terms of both species and density. Mean species per sample was 9 and mean density was 286 organisms per sample.
- The six dominant macrobenthic species were Vioscalba louisianae, Mulinia pontchartrainensis, Rangia cuneata, Texadina sphinctosoma, Hypaniola florida, chironomids; these comprise 93 percent of the total abundances. Average dry weight was 3.3 gm/m^2.

- Large *Rangia cuneata* ($\geq$ 30 mm) were found restricted to shallow waters, especially along the north shore; smaller individuals ($\leq$ 10 mm) were common in the open lake.
- Through the use of a cluster analysis of the macrobenthos, seven groups of stations were identified. Each group was characteristic of locales within the lake. For example, one group was predominantely a low salinity group and was found in the western sections; another group preferred higher salinity in the eastern sections; one group seemed characteristic of sediments subject to urban influences; and finally, one group was characteristic of dredged areas..

CHAPTER 12. NEKTON OF LAKE PONTCHARTRAIN, LOUISIANA, AND ITS SURROUNDING WETLANDS

- During 1978, 85 fish species (77 percent of its known fish fauna) were identified in the environs of the lake. Four species dominate the fish population: anchovy, croaker, menhaden, and silverside. These four species comprise 80 percent of the fish population.
- The fish community of Lake Pontchartrain is considered a transient fauna. It is composed of 55 lake species, 22 marsh species, and 8 species resident to both areas.
- Eight of the most abundant species are primarily marsh dwellers. They are: sheepshead minnow, rainwater killifish, sailfish molly, mosquitofish, spotted sunfish, bluegill, redear sunfish, and least killifish.
- The seasonal faunal similarity pattern in the lake is very much like that of the marsh, with 26 and 27 species found during all four seasons.

- Fish species found only in the marsh are primarily freshwater and euryhaline in character. These are the bowfin, carp, yellow bullhead, saltmarsh killifish, freshwater silverside, white bass, flier, longear sunfish, black crappie, and green goby.
- The numbers of fish increase during spring, peak during July, and then gradually decrease during late summer and fall. This is a typical pattern of estuarine recruitment.
- Of the 20 most abundant fish species, 9 are primarily lake in habitants and 11 use the marsh.
- The anchovy is the most ubiquitous species in the Lake Pontchartrain area. It is found almost year-round in both the lake and the marsh.
- Young croaker are abundant in most open water areas of the lake from spring through fall. They seem to avoid areas of heavy vegetation and marsh habitats.
- Juvenile menhaden use inshore beach and marsh areas as their primary habitat, but as they become larger, they move to the open waters of the lake.
- Young spot use the shore grassbeds as their primary habitat between June and September, but when they become larger, they use the open waters of the lake.

CHAPTER 13. ASPECTS OF THE LIFE HISTORY OF ANCHOA MITCHILLI CUVIER AND VALENCIENNES IN LAKE PONTCHARTRAIN, LOUISIANA, JANUARY THROUGH DECEMBER 1978

- Anchovies are one of the dominant fishes of Lake Pontchartrain and comprise about 29% of the LSU total nekton catch in terms of number.

- Anchovies generally increase in number from winter through fall.
- Anchovies occurred at all stations--open lake, shoreline, and marsh--but seem to be more abundant in the open waters of the lake.
- Anchovy spawning may start in March and cease in October or November.
- Anchovies were most abundant in waters having temperatures between 20° to 30° C and salinities between 2°/₀₀ to 4°/₀₀.
- Growth of anchovies is greatest during spring (March and April) and averages about 12 mm/month.

CHAPTER 14. GUT CONTENTS OF FORTY-FOUR LAKE PONTCHARTRAIN, LOUISIANA, FISH SPECIES

- Fishes of Lake Pontchartrain feed primarily within a benthic or a planktonic-nektonic food web. Detritus probably input to nekton via numerous invertebrate detritivores that are used as food by fishes. Relatively few Lake Pontchartrain fishes seem to derive nourishment directly from detritus; however, mullet and menhaden are detritus consumers.
- The benthic food web of Lake Pontchartrain is composed primarily of worms, mollusks, crabs, insect larvae, amphipods, and isopods. Each of these forms is fed upon by at least 10 fish species.
- The plankton-nekton food web of Lake Pontchartrain is composed primarily of mysids, copepods, decapods, and fishes. Each of these forms is fed upon by at least seven fish species.
- Fish species like the sheepshead and pinfish, which have a generalized diet and the ability to feed effectively on hard surfaces, might have advantages in future years over other fish species in Lake Pontchartrain.

- The grassbeds and those areas with high concentrations of bivalves and snails are critical fish habitats. Turbid or muddy waters could endanger these habitats.
- Most fishes of Lake Pontchartrain tend to be generalists or facultative in their feeding habits.
- Similar fish species, like the blue and channel catfish and the sand seatrout and spotted seatrout, "avoid" competition for food by using different locations of the lake such as shoreline areas as opposed to mid lake.

CHAPTER 15. MACROPLANKTON MOVEMENT THROUGH THE TIDAL PASSES OF LAKE PONTCHARTRAIN

- Salinities were significantly different among the three tidal passes. The Inner Harbor Navigation Canal (IHNC) had the most saline waters, followed by the Chef Menteur Pass, and then The Rigolets.
- Water temperatures were significantly different among the three tidal passes. The IHNC had the highest temperature, followed by The Rigolets and the Chef Menteur Pass.
- Anchovies were the dominant macroplankters collected in the tidal pass, and were followed by menhaden, blue crab, croaker, gobies, grass shrimp, and brown shrimp. These were followed by 41 less common species.
- There were no significant numerical differences in the monthly movements of macroplankton through the three tidal passes of Lake Pontchartrain.
- Macroplankton were not significantly more abundant in any of the three tidal passes although the mean catch per sample was highest in the IHNC.

- Most of the species collected moved through the tidal passes at the mid-depth and bottom levels.
- More organisms move through the three tidal passes at night than during the day and on a flood rather than ebb tide. The tide apparently acts differently in each pass because of their different physical configurations, and tidal action affects the movement of macroplankton.
- Selected species differences were found in terms of monthly collections, tidal passes, depth, light, and tidal cycle.

CHAPTER 16. SELECTED COMMERCIAL FISH AND SHELLFISH DATA FROM LAKE PONTCHARTRAIN, LOUISIANA, DURING 1963-1975, SOME INFLUENCING FACTORS, AND POSSIBLE TRENDS

- Blue crab dominates the commercial fishery of Lake Pontchartrain and comprises two-thirds of the total value and about four-fifths of the total volume.
- Shrimp and fishes account for about 19% and 14%, respectively, of the total catch value and about 10% each of the total catch volume.
- The shrimp catch is composed mainly of two species, i.e., brown shrimp (*Penaeus aztecus*) and white shrimp (*P. setiferus*).
- Commercial fish species are mainly catfishes and sea trout.
- Many factors probably influence commercial fish harvest in Lake Pontchartrain, including: natural envirionmental factors such as rainfall, salinity, temperature, turbidity, and substrate; natural biological factors, such as competition and predation; and man-induced factors, such as, the Mississippi River Gulf Outlet, the Bonnet Carre Floodway, dredging, shore alterations, loss of grassbeds, industrial and urban discharges, and various economic factors.

- Harvest data of blue crab, shrimp, and catfish from Lake Pontchartrain suggest a downward trend for all species. This condition is probably occurring each year by insignificant increments, which makes discussion and evaluaton difficult.

CHAPTER 17. PRELIMINARY SURVEY OF HIGHER VERTEBRATES OF LAKE PONTCHARTRAIN, LOUISIANA

- There are three macrohabitats for higher vertebrates in the Lake Pontchartrain drainage basin: the forested wetlands, the marshes, and the lake itself.
- Summer and winter conditions in all three habitats probably show the greatest differences of the vertebrate species composition and feeding habits.
- Preliminary food web analysis was done by means of the following index:

$$\% \text{ connection} = \frac{\text{observed connections}}{\text{possible connections}} \times 100$$

This index expresses the amount of connectivity between the predator and its food; for example, the connectivities among vertebrates and their food in the take are 27% and 36%, respectively, during summer and winter.

- Respective connectivities in the marshes are 40% and 38%, respective connectivities in the forested wetlands are 36% and 40%.

CHAPTER 18. RECENT LAND USE CHANGES IN THE LAKE PONTCHARTRAIN WATERSHED

- The surface area of Lake Pontchartrain is increasing by 15 ha/yr compared to 0.5 ha/yr for Lake Maurepas.

- Within part of the Lake Pontchartrain watershed (about 16,000 km^2 or 6,200 mi^2), urban areas occupy 6% of the total surface area; agricultural lands, 22%; upland forested land, about 40%; and wetland, about 16%.
- Forty percent of the Lake Pontchartrain watershed is deforested, and the remaining 60% has less vegetation per acre than in 1700. This may have increased fresh water flow to Lake Pontchartrain. Secondary effects of this may be sedimentation and increased nutrient concentrations in Lake Maurepas. Also, there may be a decline in soil fertility in the upper part of the watershed.
- Man-made features, canals and navigational channels, have especially increased in the Lake Pontchartrain watershed near the Mississippi River and near New Orleans.
- About 60% of the original vegetation of Lake Pontchartrain watershed remains, and its species composition is being changed to softwoods. The original forest swamps near Lakes Maurepas and Pontchartrain now have few trees that they may now be functionally marshes.
- Agricultural land between Baton Rouge and New Orleans has increased threefold between 1954 and 1972; agriculture has also increased in the rest of Lake Pontchartrain watershed.
- Land use changes with Lake Pontchartrain watershed probably affects Lake Pontchartrain by increasing water runoff and decreasing salinity and by increasing nutrient and sediment loading.

CHAPTER 19. URBANIZATION, PEAK STREAMFLOW, AND ESTUARINE HYDROLOGY (LOUISIANA)

- Vegetation cover in the northwestern part (Baton Rouge) of Lake Pontchartrain has not changed significantly over the last 30 years, but its urban population increased tenfold along with more drainage culverts, street pavements, levees, ditches, and stream channelization.
- Peak flood discharge and flood frequency on the Comite River at Comite, Louisiana, increased 23% and 50%, respectively, between 1951 and 1970 as a result of changing land uses near Baton Rouge, Louisiana. Potential peak flood discharges have increased on the Amite River by 29% and on the Comite River by 37%.
- The amount of water runoff has not changed. However, peak discharge during storms has increased.
- These changes in streamflow also influence erosion rates, downstream nutrient concentrations, and the biology of wetlands downstream.
- Nutrient concentrations and phytoplankton distributions and abundances in Lake Maurepas are probably being changed, and this in turn would affect Lake Pontchartrain.
- Instantaneous flushing rates of Lake Maurepas during storm events have increased about 30% since the 1950's as a result of increased peak flood discharge.

SELECTED ENVIRONMENTAL TRENDS

by

James H. Stone

I believe that there are three major environmental trends within and surrounding Lake Pontchartrain. First, and probably the most important, is the continuing loss of wetlands. Second, there is the increase of nutrients coming into the lake and its surrounding wetlands. Third, there is the decrease in water clarity (increase in the turbidity) of the lake's water. Each of these is briefly discussed below with selected data.

1. Loss of Wetlands

The wetlands surrounding Lake Pontchartrain are important because they provide much of the energy needed to run the Lake Pontchartrain ecosystem but also because they act as a nursery or habitat for important commercial species. There is, however, a downward trend in the total wetland area within the Lake Pontchartrain basin or drainage area (Fig. 1). Since 1900, almost one half of it has been destroyed, and most of this loss has occurred since 1950.

2. Increase in Nutrients

Nutrients coming into Lake Pontchartrain are increasing (Fig. 2). Since 1900, the loading rate of phosphorus has almost doubled, and projections indicate a continual increase unless remedial actions are taken.

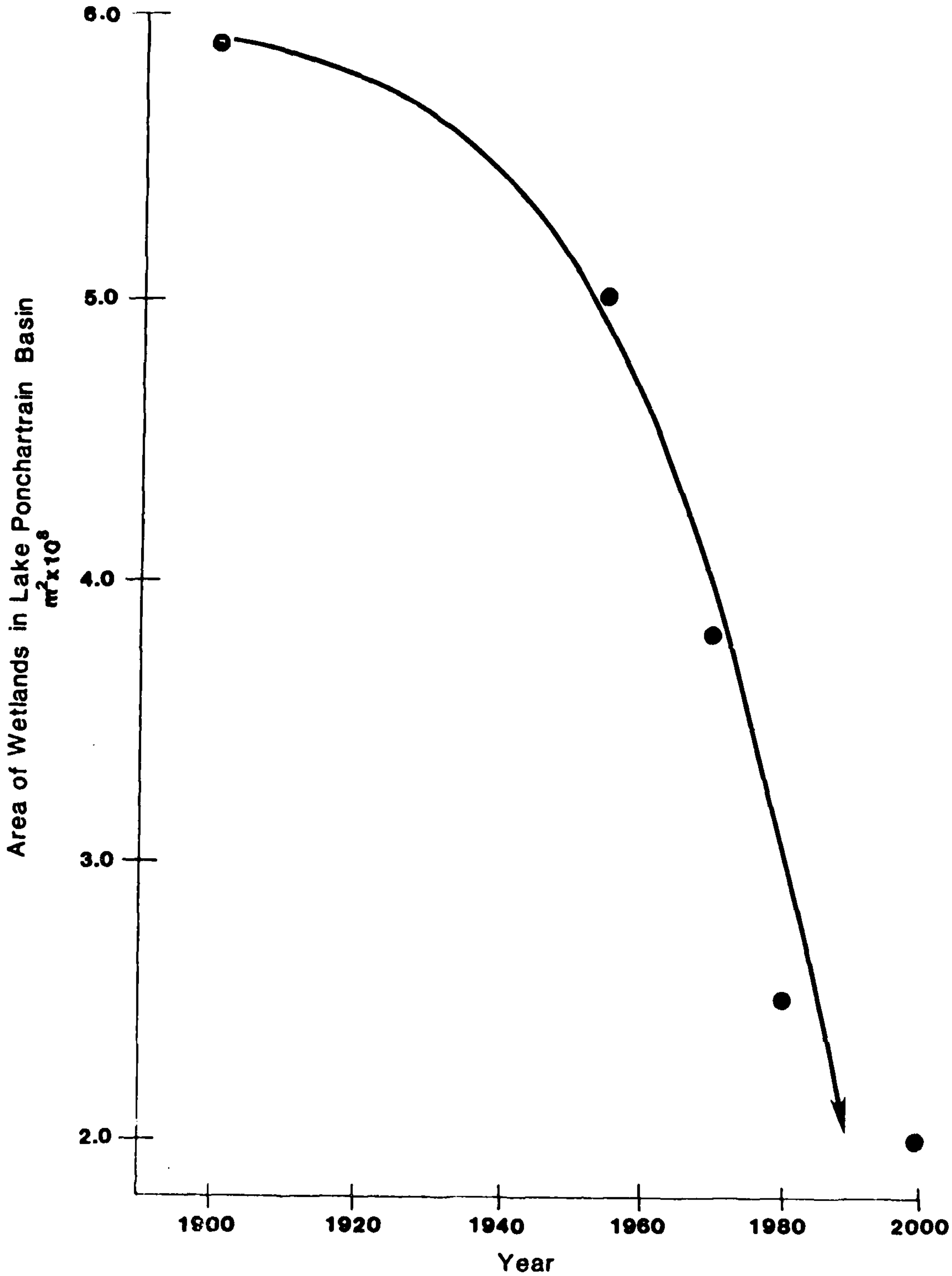


Figure 1. Amounts of wetlands in Lake Pontchartrain Basin as a function of time (R. E. Hinchee, 1977, M.S. thesis, Louisiana State University, Baton Rouge, LA 70803).

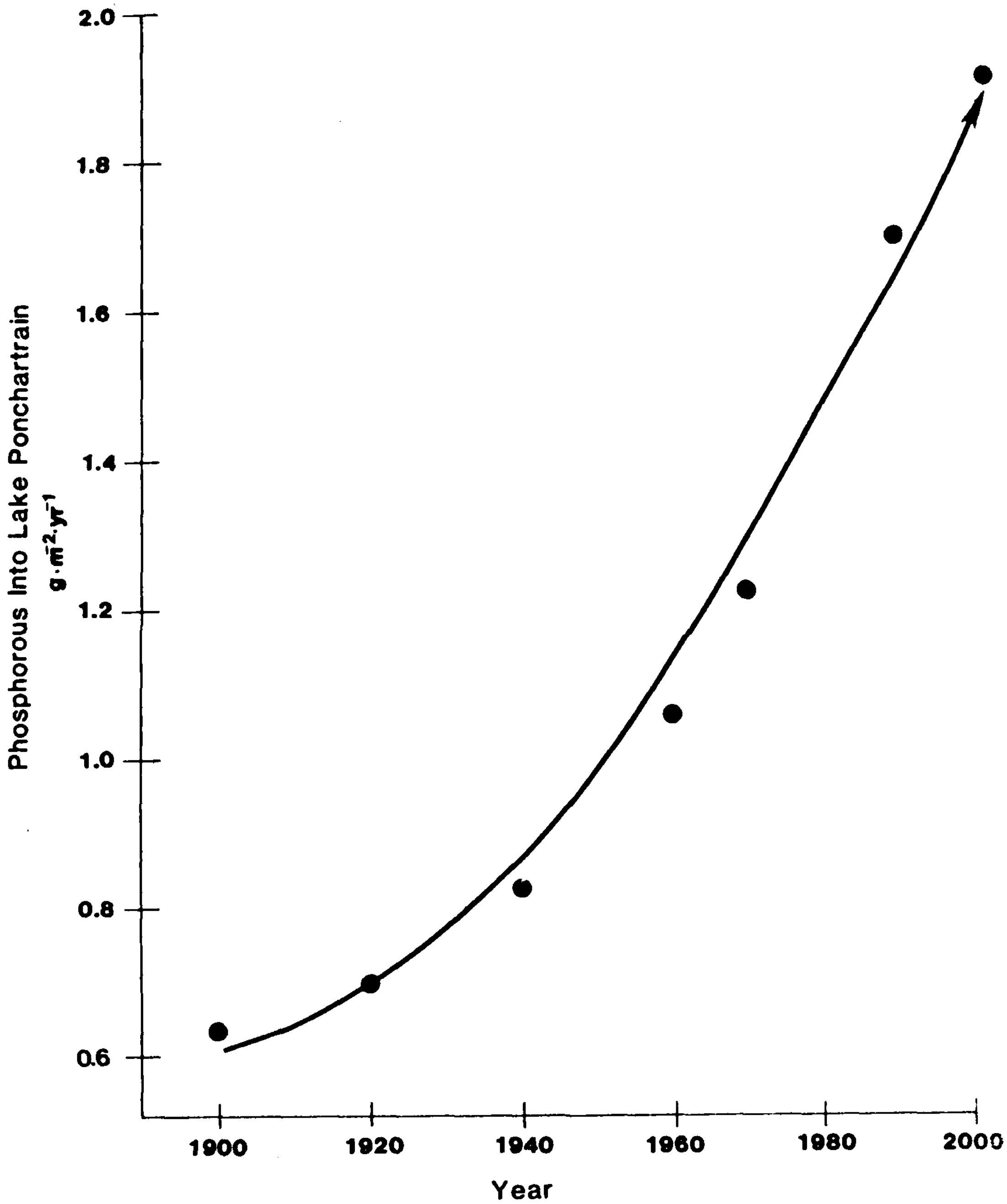
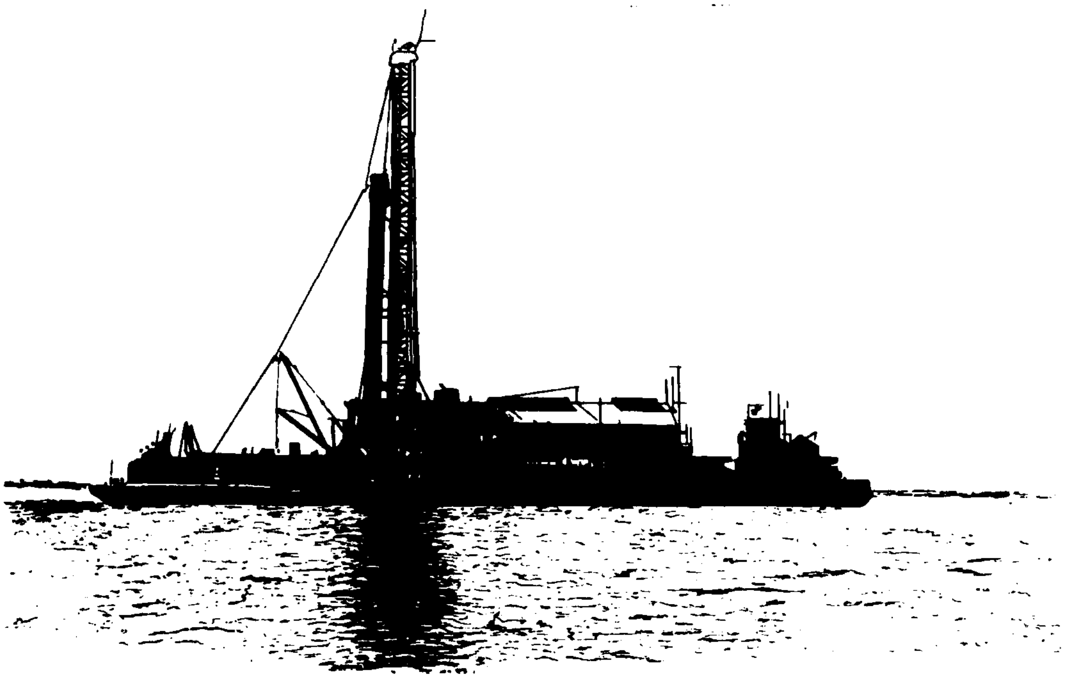


Figure 2. Phosphorous loading into Lake Pontchartrain, LA, as a function of *time* (*from* P. Kemp, 1977, in Cumulative impact studies in the Louisiana coastal zone: eutrophication and land loss. Final report to Louisiana Department of Transportation and Development by the Center for Wetland Resources, Louisiana State University, Baton Rouge, LA 70803).

3. Decrease in Water Clarity

Water transparency or clarity is decreasing in Lake Pontchartrain. Since 1953, it has decreased by about 50 percent (Fig. 3).



Petroleum drilling rig and support

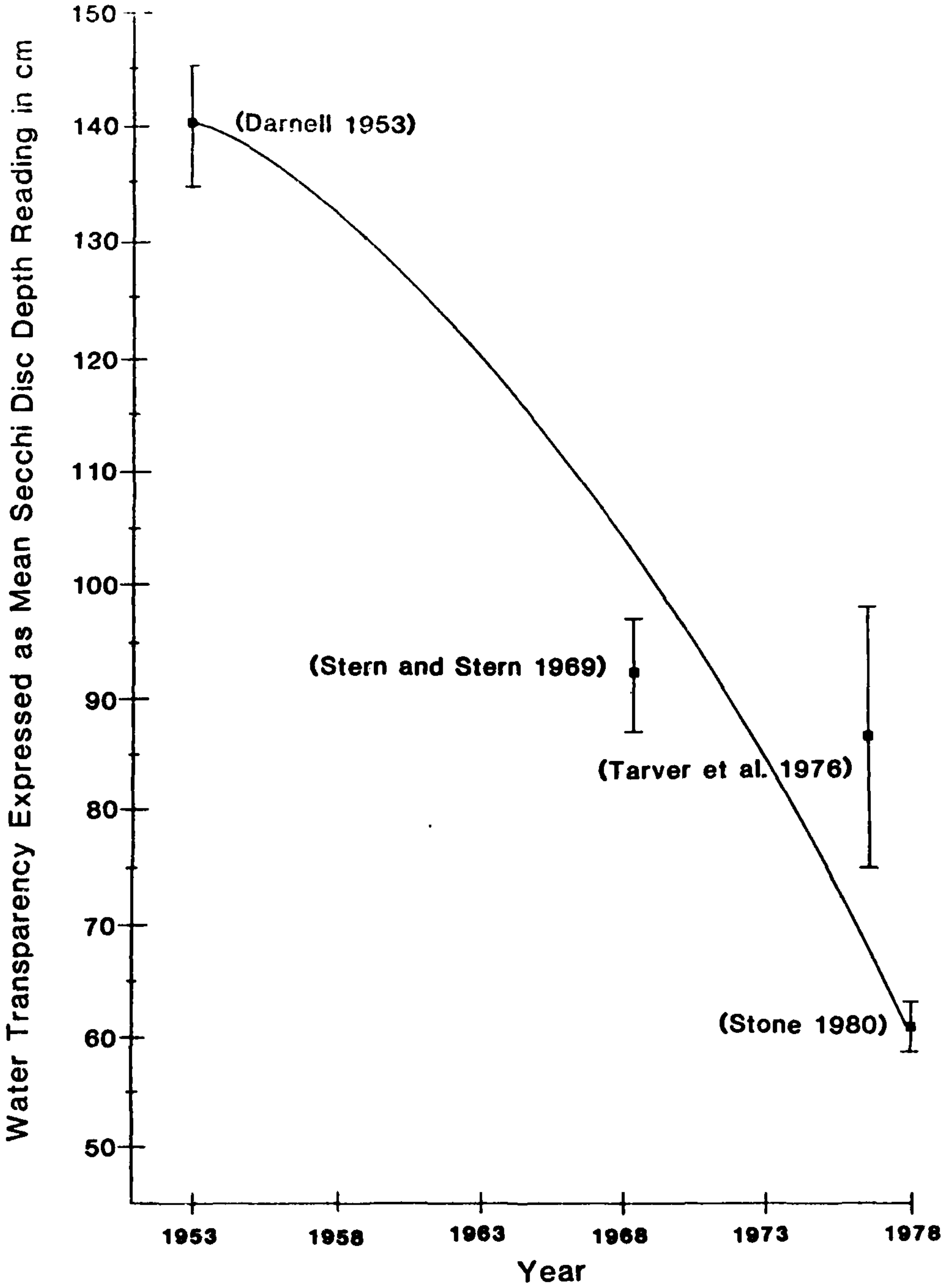


Figure 3. Water transparency expressed as mean Secchi disc reading in cm as a function of time. Standard error of mean is expressed as vertical ars. (Source: R. M. Darnell, 1979. Hydrography of Lake Pontchartrain, Louisiana, during 1953-1955. Unpublished M.S., Coastal Ecology Laboratory, Center for Wetland Resources, Louisiana State University, Baton Rouge, LA 70803; Stern, D. H., M. S. Stern, 1969. Physical, chemical, bacterial, and plankton dynamics of Water Resources Research Institute. Louisiana State University, Baton Rouge, LA 70803; Tarver, J. W. and L. B. Savoie, 1976. An inventory and study of Lake Pontchartrain-Lake Maurepas estuarine complex. Section II. Zooplankton distribution and abundance. pp. 57 to 144. Technical Bulletin No. 19. Louisiana Wildlife and Fisheries Commission, Oysters, Water Bottoms and Seafoods Division).

RECOMMENDATIONS FOR RESEARCH

by

James H. Stone

Our data from the Lake Pontchartrain ecosystem suggest a variety of courses for future research.

We recommend research be initiated on the following:

1. The fate of nutrients entering the lake.
2. The extent and role of toxins in the lake.
3. The extent and general health of the submerged grassbeds.
4. The environmental quality of all existing wetlands.
5. Selected studies on interactions between the benthos and the nekton.

Chapter 1

PRELIMINARY MODELING OF THE LAKE PONTCHARTRAIN ECOSYSTEM BY COMPUTER SIMULATIONS

by

James H. Stone
and
Linda A. Deegan

ABSTRACT

A six compartment model was developed to simulate changes of and interactions among the major trophic levels of the Lake Pontchartrain ecosystem. Three conditions were simulated: (1) pre-1978, (2) 1978 using a Secchi disc factor for 1953-1955, and (3) 1978 using a Secchi disc factor for 1978. The model assumes steady-state conditions, donor dependent and linear transfer coefficients, and a homogeneous distribution of organisms and materials. Computer simulations estimate fish production in Lake Pontchartrain has been reduced by 49% since 1900 because of wetland destruction. Grassbeds account for 26% of fish production but their (and the marshes) nursery value is greater than their potential as a food source. The increase of turbidity (62%) since 1953 can account for about 6% reduction in fish production.

INTRODUCTION

A computer model should be used only as a guide and an aid in the analysis, interpretation, and presentation of data. Models are not panaceas for solving environmental problems but if used judiciously, they can provide insight into the interactions of various ecological

processes that are not intuitively apparent. Simulation results can also verify and corroborate the findings of field research.

The purpose of this effort was to model and simulate the storage and flow of energy through the major trophic levels of the Lake Pontchartrain ecosystem. These stimulations were also designed to use data from the 1978 Louisiana State University (LSU) survey of Lake Pontchartrain in order to compare the effects of turbidity in the Lake Pontchartrain ecosystem.

MODEL DETAILS

We developed a six compartment model to simulate changes of and interactions among the major trophic levels of the Lake Pontchartrain ecosystem (Fig. 1). The model consists of six state variables (Table 1 and Appendix 1) with 22 terms of interactions between variables and three external forcing functions (Table 2 and Appendix 2).

Coefficients (Table 2) describing pathways of carbon flow were based on general physiological principles and on previous food web analyses of Lake Pontchartrain. All fluxes or transfers were donor dependent. Coefficients were linear and assumed steady-state conditions. Average monthly water temperatures (from Thompson and Verret, Chapter 12) and average insolation in tenth year intervals (Day et al. 1973) were used to simulate the two forcing functions for grassbeds and phytoplankton. Nutrient input, the other forcing function for organic detritus, was simulated as a sine wave. The effects of turbidity were modeled as a simple, linear constriction of the euphotic zone and were based on Secchi disc depth readings as follows:

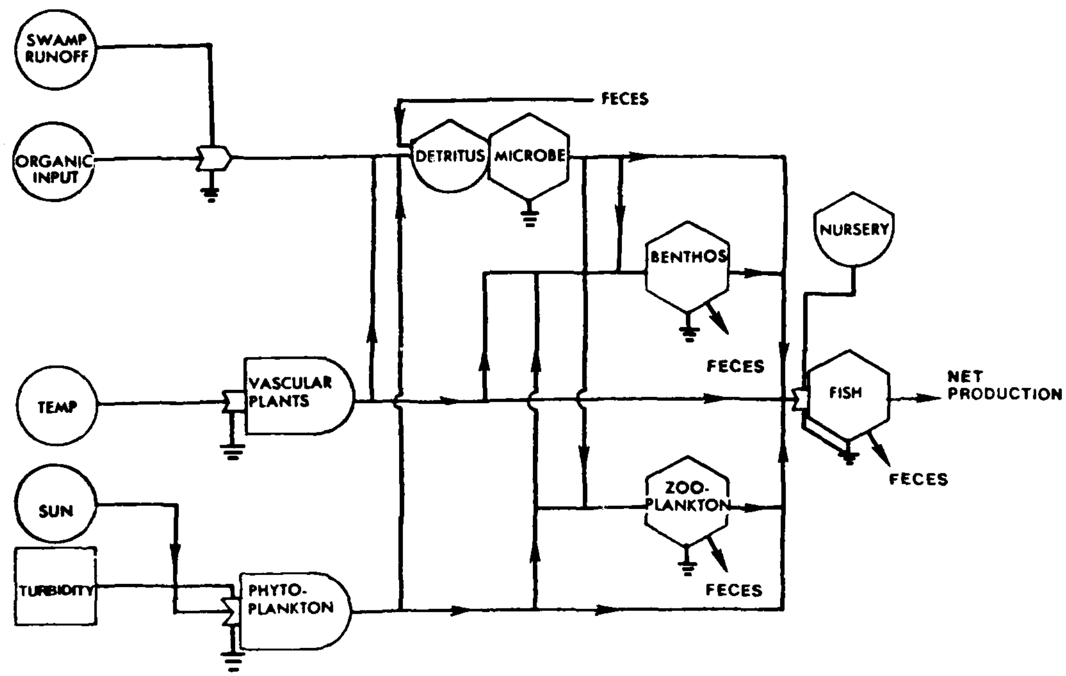


Figure 1. Conceptual model of Lake Pontchartrain ecosystem used for computer simulations (modified from Hinchee 1977).

Table 1. Initial Conditions of State Variables. Data for Computing these Conditions are given in Appendix 1

State Variable		Designation	Value	
			Pre-1978	1978
I.	Vascular plants of the grassbeds	P2	5.0	5.0
II.	Phytoplankton	P3	3.3	3.3
III.	Detritus	D4	500.00	500.00
IV.	Benthos	B5	1.91	25.00
V.	Zooplankton	H6	1.30	0.15
VI.	Fishes	F7	2.35	0.175

Table 2. Pathway Coefficients and Flux Rates. Details for Calculation of these Values are Given in Appendix 2

Description	Designation	Rate Value Pre-1978	Rate Value 1978	Flux Value Pre-1978	Flux Value 1978	[illegible]
I. Grassbed Losses						
1) Detritus	RC24	2.80	113.800	14.00	574.57	
2) Benthic consumption	RC25	0.60	5.060	3.00	25.31	
3) Fish consumption	RC27	0.60	0.023	3.00	0.117	
II. Phytoplankton Losses						
4) Detritus	RC34	112.12	13.330	370.00	44.01	
5) Benthic consumption	RC35	2.12	12.780	7.00	42.19	
6) Zooplankton consumption	RC36	2.42	0.322	8.00	1.063	
7) Fish consumption	RC37	0.30	0.118	1.00	0.118	
III. Detritus Losses						
8) Benthic consumption	RC45	0.24	1.550	122.00	776.25	
9) Zooplankton consumption	RC46	0.28	0.024	142.00	12.23	
10) Fish consumption	RC47	0.08	0.003	39.00	1.52	
11) Respiration	RC4R	1.35	1.35	677.00	677.00	
IV. Benthic Losses						
12) Detritus	RC54	0.52	0.40	68.00	337.5	
13) Fish consumption	RC57	16.23	0.048	31.00	1.21	
14) Respiration	RC5R	17.28	18.25	33.00	456.25	
15) Production excess	RC5P	---	1.95	---	48.79	
V. Zooplankton Losses						
16) Detritus	RC64	0.61	0.40	91.00	5.317	
17) Fish consumption	RC67	10.00	3.43	13.00	0.507	
18) Respiration	RC6R	35.38	43.77	46.00	6.480	
19) Production excess	RC6P	---	6.58	---	0.974	
VI. Fish Losses						
20) Detritus	RC74	0.34	0.20	30.00	0.678	
21) Respiration	RC7R	16.17	13.505	38.00	2.36	
22) Production	RC7M	8.00	2.00	19.00	3.50	
VII. Effects of External Forcing Functions						
• Celsius temperature (temp) on grassbed production						FO2 = 0.2[illegible] (temp)
• *Insolation* (sun) on phytoplankton production, modified by turbidity						FO3 = 0.[illegible] (sun) * Secchi [illegible] Depth
• Inorganic input to detritus from swamps by seasonal flooding						FO4 = [illegible] 271.3 [Sin(6.2[illegible] x [illegible])]

$$\text{Turbidity Factor 1}_{\ 1953\text{-}1955} = \frac{\text{Secchi disc depth in cm Darnell 1953-1955}}{\text{Average depth of Lake Pontchartrain in cm}} = \frac{117 \text{ cm}}{305 \text{ cm}} = 0.384$$

$$\text{Turbidity Factor 2}_{\ 1978} = \frac{\text{Secchi disc depth in cm LSU 1978}}{\text{Average depth of Lake Pontchartrain in cm}} = \frac{72 \text{ cm}}{305 \text{ cm}} = 0.236$$

Factors 1 and 2 were separately multiplied by the insolation forcing function to simulate the effect that differing amounts of suspended sediments would have on photosynthesis by phytoplankton. This assumes a linear relationship between primary production of phytoplankton and Secchi disc depth. We believe that data given in Dow and Turner (Chapter 7) justify this assumption.

The differential equations, which define changes in state variables, are simple multiplicative functions based on fluxes in and out of the compartment. The model program was written in IBM's (1969) Continuous System Modeling Program (CSMP), and differential equations were solved using a Runge Kutta integration scheme on an IBM 370 digital computer. The total time period for each simulation was four years; the integration interval was 0.01 years. A complete listing of the computer program is given in Appendix 3.

The major assumptions of this model are: (1) steady-state conditions, (2) donor biomass dependent, linear transfer coefficients, and (3) homogeneous distribution of the various materials.

RESULTS

Table 3 summarizes the results of our simulations. Condition 1 was simulated by using data from various sources and not necessarily data

Table 3. Results of Computer Simulations of Lake Pontchartrain Ecosystem as Indicated in Figure 1 in Terms of (A) Average ($\bar{X}$) Biomass, and (B) Average ($\bar{X}$) Production per Trophic Level in Grams Carbon (C) per m^2 per year

Simulation	(1) Pre-1978	(2) 1978 (53 Secchi)	(3) 1978 (78 Secchi)
		A. Biomass ($\bar{X}gC \cdot m^{-2} \cdot yr^{-1}$)	
1. Grassbeds	5.05	5.21	5.21
2. Phytoplankton	3.24	2.73	1.69
3. Zooplankton	1.26	0.16	0.15
4. Detritus	497.91	489.50	469.58
5. Benthos	1.85	26.87	25.43
6. Nekton	0.23	0.78	0.69
		B. Production ($\bar{X}gC \cdot m^{-2} \cdot yr^{-1}$)	
1. Grassbeds	20.00	597.00	597.00
2. Phytoplankton	365.00	136.44	84.73
3. Zooplankton	13.00	1.48	1.39
4. Detritus	407.00	984.60	921.10
5. Benthos	31.00	49.54	46.87
6. Nekton	19.00	1.33	1.26

obtained from Lake Pontchartrain; they were the best available estimates prior to our 1978 survey (for details, see Hinchee 1977). It is apparent that our initial (pre-1978) simulations were, in some cases, significantly different from our 1978 data and estimates. Despite these limitations our initial conditions show several features. For example, the simulations of condition 1 estimated that fish production in Lake Pontchartrain has been reduced by 49% since 1900 because of the loss of wetland (Table 4). In addition, these simulations project a 26% loss in fish production if the grassbeds were eliminated (Fig. 2). It was also estimated that the nursery value of the grassbeds and the marshes is three and four times, respectively, more important than their potential as a food source (for additional details, see Hinchee 1977).

Conditions 2 and 3 use 1978 data and estimates and are based on Secchi disc readings for 1953 and 1978, respectively. The most apparent difference between these two conditions is that phytoplankton production is reduced, as a result of increasing turbidity, by 38% (reduced from 136 to 85 g $C \cdot m^{-2} \cdot yr^{-1}$; Table 3). In addition, zooplankton production is reduced by about 6%; benthic and fish production, each by about 5%. Conditions 2 and 3 indicate that biomass and production of both zooplankton and benthos are one order of magnitude greater than was obtained from simulations of condition 1. In addition, fish biomass and production for conditions 2 and 3 are about one order of magnitude smaller than obtained from simulations of condition 1.

DISCUSSION

Simulations of condition 1 demonstrate the importance of small nursery areas, such as the grassbeds and marshes, to the Lake Pontchartrain

Table 4. Fish Production Changes as the Result of Wetland Destruction Since 1900 With the Projected Draining of the St. Charles Parish Marsh in Two Steps, One in 1980 and One in 1990 (Hinchee 1977)

	Marsh Area	Linear Output	
Years	m^2	gm org$\cdot m^{-2} \cdot yr^{-1}$	Percent Change From 1900
1900-1908	5.9×10^8	36.6	----
1908-1948	4.7×10^8	33.6	-8.2
1948-1964	5.0×10^8	30.9	-15.6
1964-1968	3.8×10^8	23.8	-35.0
1968-1980	3.0×10^8	18.8	-48.6
1980-1990	2.5×10^8	15.8	-56.8
1990-2000	2.0×10^8	12.7	-65.3

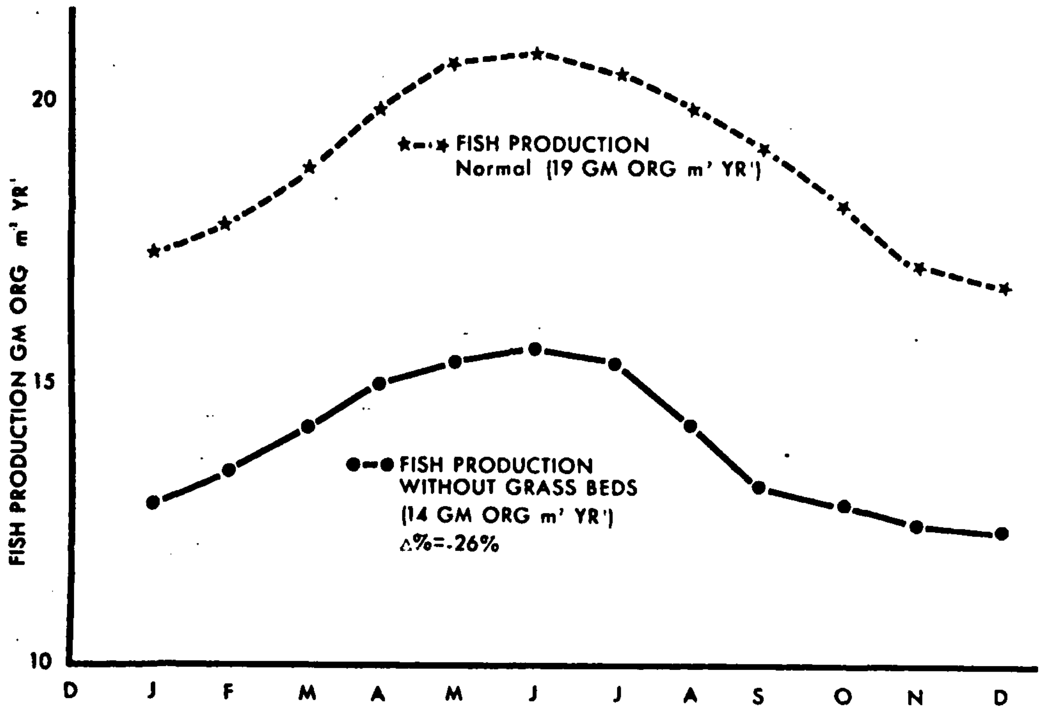


Figure 2. Fish production for a one-year period before and after destruction of grassbeds as simulated by the linear model (Hinchee 1977).

ecosystem. For example, these areas represent about 6% of the total basin area and yet account for most of the fish production in the basin and provide for most of their nursery needs.

Conditions 2 and 3 show the potential effect that increasing turbidity may be having on the Lake Pontchartrain ecosystem. Turbidity reduces phytoplankton biomass and production, which in turn reduces zooplankton, benthos, and nekton. It seems likely that these effects have occurred each year by insignificant increments. Conditions 2 and 3 also indicate that the high zooplankton and benthic biomass and production do not seem to be directly linked, as they should be, to nekton biomass and production since the latter values are quite small compared to the data of zooplankton and benthos.

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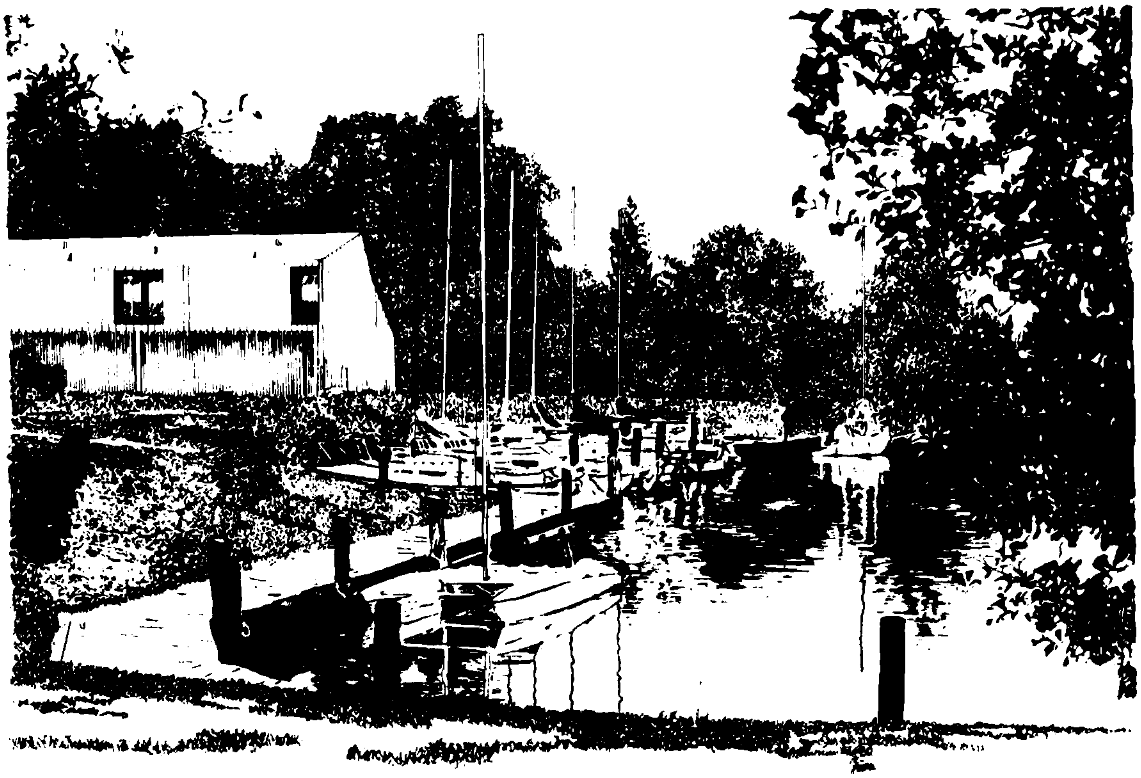


Apartments and marina on Lake Pontchartrain north shore

APPENDIX 1

DATA AND CALCULATIONS FOR COMPUTING THE INITIAL CONDITIONS OF SIX STATE VARIABLES

1) Vascular plants biomass for both models was calculated assuming the average lake plant biomass was 100 gm C/m^2 (Fannaly 1975) and that 5% of the lake was covered by grassbeds (Perret et al. 1971).

2) Phytoplankton biomass was calculated assuming Lake Pontchartrain had an average chlorophyll content similar to Barataria Bay (7.6×10^{-3} mg/m^3; Sklar 1976); a chlorophyll to organic matter ratio of 2×10^{-3} mg chlorophyll to 1 gm organic matter (Wright 1959); and a one meter photic zone.

3) Detritus biomass was assumed to be the same as Day et al. (1973) reported for Barataria Basin.

4) Pre-1978 benthos biomass estimates were made from biomass and density estimates reported for <u>Rangia</u> (Fannaly 1975, Tarver and Dugas 1973), crabs and shrimp (Kneiper 1975, Suttkus et al. 1954), and other soft bodied benthos (Fannaly 1975). Estimates for 1978 were from this study (Chapter 11).

5) Pre-1978 zooplankton biomass was set at 1.3 gm C/m^2 to solve the overall energy flow balance. Estimates for 1978 were from this study (Chapter 8).

6) Pre-1978 fish biomass was calculated based on: occurrence data reported by Suttkus et al. (1954); biomass estimates developed by Knieper (1975); and assuming a trawl catch efficiency of 20% and a wet weight to organic matter conversion factor of 0.2 (Day et al. 1973). Estimates for 1978 were from Fannaly (1979).

APPENDIX 2

CALCULATION OF PATHWAY COEFFICIENTS

I. Grassbed Losses

1) Losses to detritus were calculated as all production not consumed by fish or benthos. The pre-1978 model assumed a production biomass ratio of 4 to 1. Average yearly production for the 1978 model was assumed to be 600 g $C \cdot m^{-2} \cdot yr^{-1}$ (Phillips 1978).

2) Benthic consumption was calculated as a percentage of total benthic consumption based on percent composition of gut contents (Darnell 1961). Vascular plants represented 3% of benthic consumption.

3) Fish consumption was calculated the same way as benthic consumption, with vascular plants representing 3.45% of total fish consumption.

II. Phytoplankton

4) Losses to detritus were calculated as production left after consumption by benthos and zooplankton. Production was determined from average insolation data, and turbidity factor.

5) Benthic consumption was calculated as percent of total benthic consumption based on percent composition of gut contents (Darnell 1961). Phytoplankton represented 5% of the total benthic consumption (Darnell 1961).

6) Zooplankton consumption was calculated in the same way as benthic consumption, assuming zooplankton gut content ratios were similar to the benthos, with phytoplankton representing 8% of total consumption.

7) Fish consumption was calculated in the same way as benthic consumption, with phytoplankton representing 1.15% of total fish consumption (Darnell 1961).

III. Detritus Losses

8) Benthic consumption was calculated as a percentage of total benthic consumption based on percent composition of gut contents (Darnell 1961). Detritus represented 92% of benthic consumption.

9) Zooplankton consumption was calculated in the same way as benthic consumption. Zooplankton gut content ratios were assumed to be similar to the benthos, with detritus representing 92% of the total consumption.

10) Fish consumption was calculated in the same way as benthic consumption, with detritus representing 44.8% of the total fish consumption.

11) Detritus respiration flux was assumed to be 135% of the standing stock (Day et al. 1973).

IV. Benthic Losses

12) Loss to detritus was calculated as feces production. Feces production was assumed to be 40% of total intake.
Total intake was calculated using Winberg's (1960) equation:

$$\text{Total intake} = 1/a \quad (\text{Respiration} \;\&\; \text{Production})$$

where the assimilation efficiency (a) was assumed to be 0.6 (Gerlach 1971).

13) Fish consumption was calculated as a percentage of total fish consumption based on percent composition of gut contents. Darnell (1961) reports 35.63% of fish consumption to be benthos.

14) Benthic respiration was assumed to be 5% wet weight per day (Day et al. 1973).

15) Production excess was defined as all production not consumed by fish. A production to biomass ratio of 2 to 1 (Gerlach 1971) was used to estimate total production for the 1978 model. The pre-1978 model set production equal to fish consumption to balance mass flow equations.

V. Zooplankton Losses

16) Loss to detritus was calculated as feces production. Feces production was assumed to be 40% of total intake (Gerlach 1971).

17) Fish consumption was calculated as a percentage of total fish consumption based on percent composition of gut contents. Darnell (1961) reports zooplankton as 14.94% of total consumption.

18) Respiration was assumed to be 12 percent wet weight per day (Day et al. 1973).

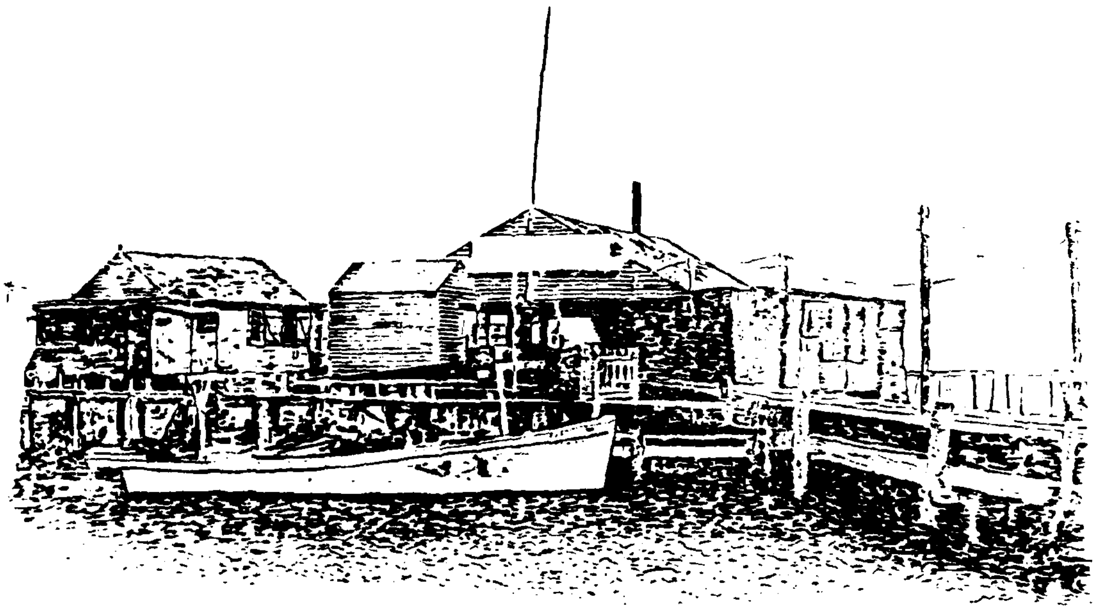
19) Production excess was defined as all production not consumed by fish. A production to biomass ratio of 10 to 1 was used to estimate total production (Day et al. 1973).

VI. Fish Losses

20) Loss to detritus was defined as feces production and assumed to be 40% of total intake (Winberg 1960). Total intake was calculated based on Winberg's (1960) equation.

21) Respiration was assumed to be 3.7% of wet weight per day (Day et al. 1973).

22) Production was calculated using a production to biomass ratio of 2 to 1 (Warburton 1979) for the 1978 model and as the area under the biomass curve for the pre-1978 model.



Boat marina and grocery

APPENDIX 3

COMPUTER PROGRAM LISTING FOR SIX-COMPARTMENT MODEL OF LAKE PONTCHARTRAIN ECOSYSTEM

```
TITLE DARNEL_S NEW SECCHI NEW DATA
INITAL
PARAMETER XNER=1.0
PARAMETER SDR=.38
INCON ICP2P=0.0
INCON ICP2=5.05,ICP3=3.3,ICD4=500.....
ICB5=25..ICH6=.148,ICF7=.175
INCON ICB5P=0.0,ICH6P=0.0
INCON ICFM7=0.0
CONSTANT RC24=113.8,RC34=39.5,RC25=5.052,...
RC36=.322,RC37=.118,RC46=.024,...
RC35=12.78,RC45=1.55,RC27=.0234,...
RC47=.024,RC57=.0483,RC67=3.43,...
RC54=.4,RC64=.4,RC74=.2,...
RC4R=1.35,RC5R=18.25,RC6R=43.77,...
RC7R=13.50,RC7M=2.0,RC55=2.0,RC58=1.95
CONSTANT RC68=6.58
CONSTANT RC66=10.00
FUNCTION TEMP = (0.,6.9,.0833,9.6,.1667,12.1,...
.25,21.9,.333,24.1,.4167,29.2,.5,29.9,.583,28.8,.6667,28.,...
.75,22.8,.8333,22.4,.9167,11.4,1.,7.)
FUNCTION SUN=(.0416,225.,.1249,285.,.2083,385.,.2916,445.,.3749,500.,
.4583,510.,.5416,470.,.6249,450.,.7083,410.,.7916,385.,.8749,280.,...
.9583,210.,1.,210.)
DYNAMIC
NOSORT
YEAR=AINT(TIME)
TIMEA=TIME-YEAR
SORT
D4P=INTGRL(ICB5P,F04+F24+F34+F54+F64+F74)
P2=INTGRL(ICP2,F02-F24-F25-F27)
P2P=INTGRL(ICP2P,F02)
P3=INTGRL(ICP3,F03-F34-F35-F36-F37)
P3P=INTGRL(ICP2P,F03)
D4=INTGRL(ICD4,F04+F24+F34+F54+F64+F74-F45-F46-F47-F4R)
B5=INTGRL(ICB5,F25+F35+F45-F57-F54-F5R)
B5P=INTGRL(ICB5P,F55)
B5L=INTGRL(ICB5P,F58)
H6=INTGRL(ICH6,F46+F36-F67-F6R-F64)
H6L=INTGRL(ICH6P,F68)
H6P=INTGRL(ICH6P,F66)
F7=INTGRL(ICF7,F27+F37+F47+F57+F67-F7M-F7R-F74)
F7P=INTGRL(ICFM7,F7M)
```

```
F04=407+271.3*SIN(6.28*TIME)
TEMPX=AFGEN(TEMP,TIMEA)
F02=(30.*TEMPX)
SUNX=AFGEN(SUN,TIMEA)
F03=(386.0*SUNX/387.8)*SDR
F55=RC55*B5
F68=RC68*H6
F66=RC66*H6
F58=RC58*B5
F24=RC24*P2
F34=RC34*P3
F4R=RC4R*D4
F5R=RC5R*B5
F6R=RC6R*H6
F7M=RC7M*F7
F7R=RC7R*F7
F25=RC25*P2
F27=RC27*P2*KNER
F35=RC35*P3
F36=RC36*P3
F37=RC37*P3*KNER
F45=RC45*D4
F46=RC46*D4
F47=RC47*D4*KNER
F57=RC57*B5*KNER
F67=RC67*H6*KNER
F54=RC54*(F45+F25+F35)
F64=RC64*(F46+F36)
F74=RC74*(F27+F37+F47+F57+F67)
PRTPLOT D4,D4P
TIMER FINTIM=4.,DELT=.01,OUTDEL=.083,PRDEL=.083
END
STOP
```

Chapter 2

A TROPHIC STATE ANALYSIS OF LAKE PONTCHARTRAIN, LOUISIANA, AND SURROUNDING WETLAND TRIBUTARIES

by

Ann Seaton Witzig
and
John W. Day, Jr.

ABSTRACT

A trophic state analysis of Lake Pontchartrain was conducted by applying data from four master stations (Pass Manchac, Open Lake, Inner Harbor Navigation Canal [IHNC], and The Rigolets) to the four variable Trophic State Index (TSI). The highly negative scores classified each station as meso-oligotrophic. This low trophic classification may be the result of several factors, such as dilution of effluent, flocculation of inflowing suspended matter in low salinity waters, or phytoplankton uptake of nutrients in the surrounding wetlands.

Quantification of the trophic state of waterbodies was through multivariate statistical analyses developed from an analysis of Barataria Basin, Louisiana. Principal component analysis identified four variables characterizing the trophic state of each waterbody. These variables were: total organic nitrogen, total phosphorus, Secchi disc depth, and chlorophyll a. Previous multivariate trophic state analyses of Florida lakes (Brezonik and Shannon 1971) using seven trophic variables were compared with the Barataria results. By modifying the Brezonik and Shannon seven variable trophic state index to four variables, a new TSI was developed that was applicable to Lake Pontchartrain.

INTRODUCTION

Widely varying water chemistry parameters characterized Lake Pontchartrain and surrounding tributary wetlands. Open lake stations (Dow and Turner, Chapter 7) were, on the average, relatively low in concentrations of total organic and inorganic nitrogen, total phosphorus, and chlorophyll *a*. Secchi disc depth, as a measure of water clarity, was high. Waterways draining the wetlands and adjacent uplands differed according to location around the lake. North shore tributaries were generally similar in nutrient concentrations but Secchi disc depth were markedly lower than in waterways measured on the western shore (Cramer and Day, Chapter 9; Cramer 1978).

Discrepancies between lake and tributary water chemistry suggested overall differences in water quality. The purpose of this research was to quantify water quality to allow objective comparisons between the Lake Pontchartrain drainage system and similar estuarine waters of Louisiana.

RESULTS

Initial comparisons between open lake stations in Lake Pontchartrain (Dow and Turner, Chapter 7) show only slight differences between mid-lake, The Rigolets, Inner Harbor Navigation Canal (IHNC), and Pass Manchac (Fig. 1, Table 1). Total organic nitrogen (TON) was highest near Pass Manchac (the western end of the lake) and lowest at The Rigolets. Inorganic nitrogen and total phosphorus were higher in both Pass Manchac and the IHNC than mid-lake or The Rigolets. Although chlorophyll *a* was slightly higher in the IHNC than the other stations, Secchi disc depth was concomitantly high.

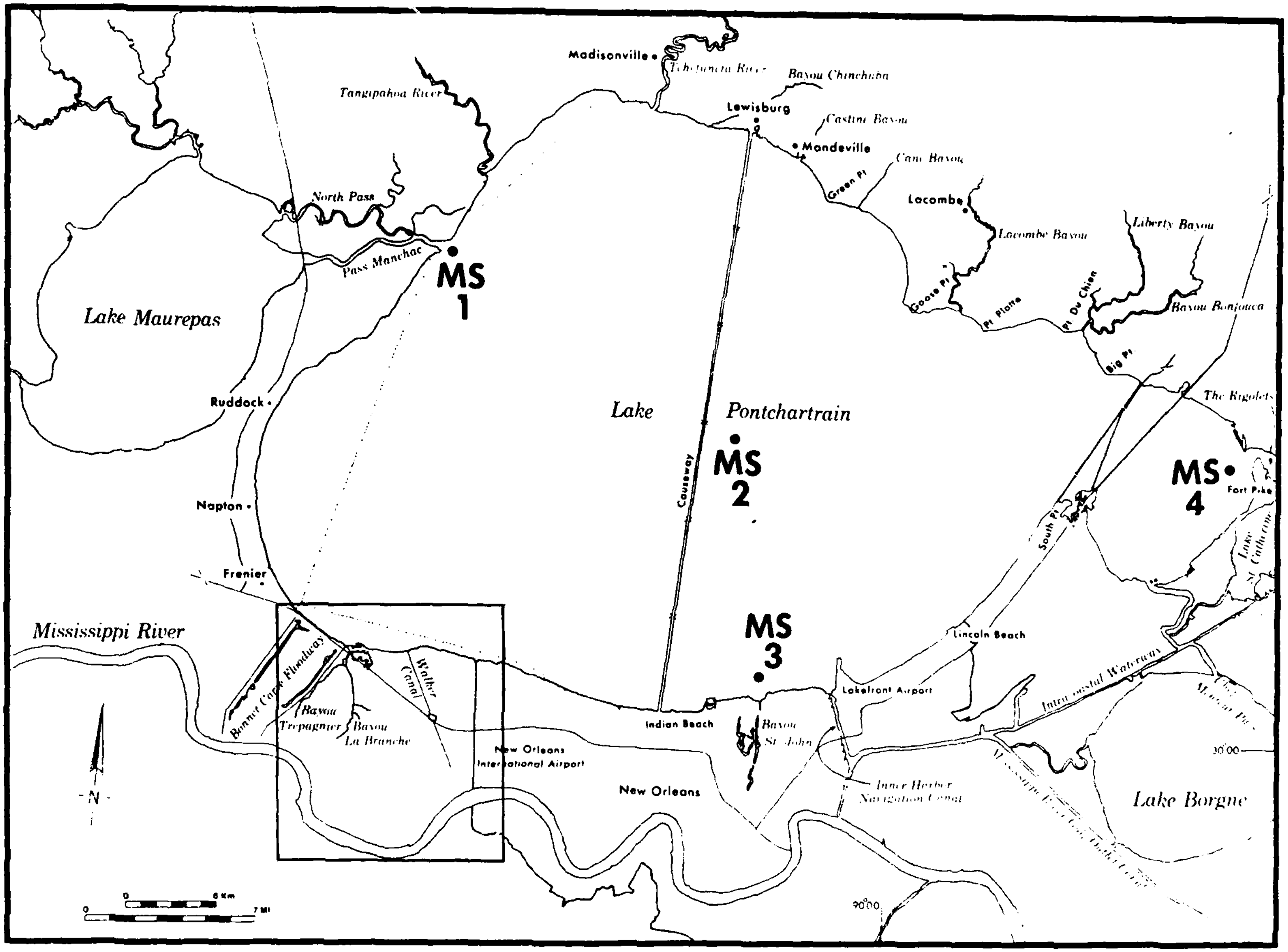


Figure 1. Lake Pontchartrain Master Stations.

Table 1. Mean Variable Concentrations at Selected Stations in Louisiana

		Total Organic Nitrogen (mg/l)	Total Inorganic Nitrogen (mg/l)	Total Phosphorus (mg/l)	Chlorophyll a (mg/m3)	Secchi Disc Depth (cm)
Pontchartrain Project Results:						
Pass Manchac		0.50 ±.02	0.15 ±.02	0.07 ±.004	7 ±3.6	76 ±38.9
Mid-Lake		0.43 ±.02	0.06 ±.01	0.05 ±.004	8 ±5.3	73 ±33.6
IHNC		0.40 ±.02	0.12 ±.12	0.09 ±.006	10 ±3.7	112 ±43
The Rigolets		0.31 ±.03	0.10 ±.01	0.05 ±.002	7 ±2.1	83 ±35.2
Goose Point		0.62 ±.06	0.07 ±.02	0.06 ±.01	--	--
Irish Bayou Lagoon		0.61 ±.05	0.08 ±.04	0.07 ±.01	--	--
New Orleans East		1.87 ±.17	0.14 ±.06	0.16 ±.03	--	--
Walker Canal		0.96 ±.12	0.39 ±.16	0.24 ±.06	--	--
Cramer 1978:						
Transect #1	Crossbayou Canal	2.01 ±.63	1.43 ±.28	1.63 ±.28	29 ±6.1	54 ±2.2
	Bayou Lapranche	1.46 ±.39	1.04 ±.17	1.15 ±.23	24 ±5.3	45 ±2.3
	Offshore Swamp	0.59 ±.06	0.21 ±.03	0.14 ±.02	8 ±1.7	69 ±11.9
Transect #2	Walker Canal	0.96 ±.12	0.30 ±.06	0.32 ±.05	13 ±2.8	54 ±4.1
	Bayou Piquant	0.69 ±.06	0.33 ±.06	0.31 ±.06	11 ±2.6	53 ±6.4
	Offshore Marsh	0.83 ±.07	0.25 ±.06	0.16 ±.02	8 ±1.3	72 ±12.7

Water chemistry of the wetland tributaries, Goose Point, and Irish Bayou Lagoon resembled that of the open lake stations (Cramer and Day, Chapter 9; and Table 1). However, the higher TON at Goose Point and Irish Bayou Lagoon compared to that at open lake stations may reflect the export of organic material from the adjacent wetlands. Inorganic nitrogen and total phosphorus, however, were within the range of concentrations found in the lake.

New Orleans East and the Walker Canal were characteristically high in both inorganic and organic nutrient concentrations (Table 1). Both waterways are situated along the southern lake shore and both drain highly developed urban areas. Concentrations in these waterways were close to twice those measured in the north shore tributaries.

Earlier transects through the waterways of the southwestern lake shore demonstrated large reductions in nutrient concentrations between the natural levee of the Mississippi River and a few kilometers offshore (Fig. 2, Table 1, Cramer 1978). The enrichment of these waterways is probably derived from upland runoff from the developed natural levee along the Mississippi River. High nutrient concentrations are evident in the wetland waterways as well as offshore. Although concentrations are considerably lower closer to those of the lake, they are high in comparison with north shore wetland tributaries (i.e., Goose Point; Table 1; Cramer and Day, Chapter 9).

Comparisons With Other Estuarine Systems

Table 2 indicates that water chemistry parameters from Lake Pontchartrain stations encompass a range of concentrations reported for other estuarine systems. Total inorganic nitrogen in the open lake stations

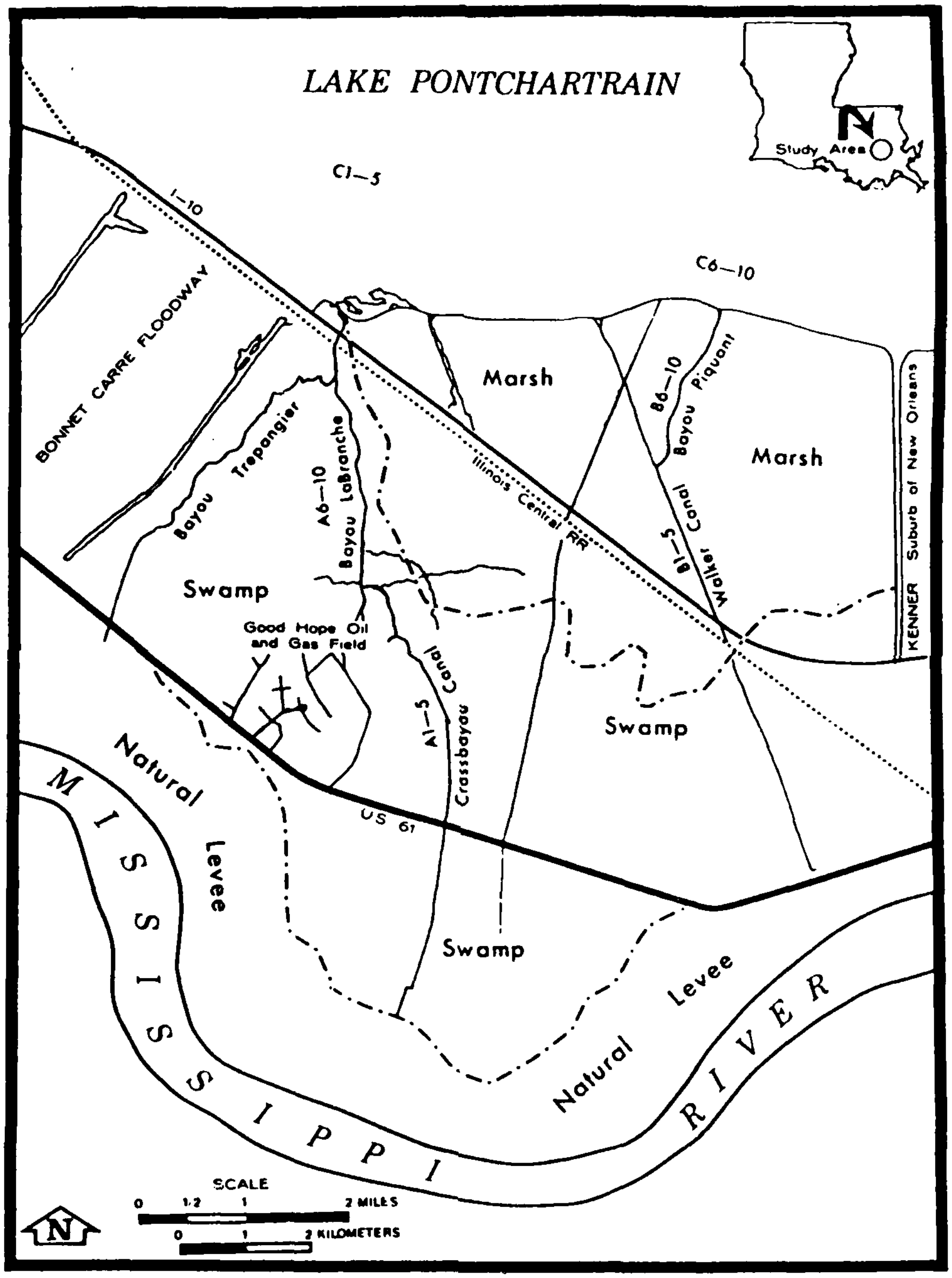


Figure 2. Map of Cramer (1978) study area.

Table 2. *Average Nutrient Concentrations from Several Estuarine Systems*

	Inorg. N	NO_3	PO_4	TP	TON	Chl. *a*	Salt
River Input							
Windom, Dunstan & Gardner 1974							
Savanah	0.31	--	0.03	--	--	--	0
Santee	0.10	--	0.01	--	--	--	0
Kuenzler et al. 1977							
North Carolina Streams							
Natural	0.49	--	--	0.09	0.24	--	0
Channelized	1.03	--	--	0.12	0.31	--	0
Jaworski et al. 1972							
Freshwater Portion Rappahannock Estuary	(0.10-0.40)	--	--	(0.05-0.08)	--	(8.0-40.0)	--
Seaton 1979							
Freshwater Portion Barataria Basin, La.	0.40	--	--	0.18	1.72	30	0
Estuarine Concentrations							
Seaton 1979							
Barataria Bay, La.	0.16	--	--	0.12	0.90	10	15.8
Caperon et al. 1971							
Kaneohe Bay, Hawaii							
(Sewage Outfall) South Section	0.06	--	0.05	--	--	2.2	--
Transition	0.03	--	0.008	--	--	0.71	--
North Section	0.02	--	0.004	--	--	0.56	--
Naiman & Sibert 1978							
Nanaimo Estuary, British Columbia							
Straight of Georgia (Surface)	--	0.18	--	0.04	--	--	--
Nanaimo Estuary Mudflat	--	0.19	--	0.05	--	--	--
Nanaimo River	--	0.04	--	0.01	--	--	--
Butler & Tibbitts 1971							
Tamar Estuary							
River	0.24	--	--	--	0.16	--	29.6
	0.09	--	--	--	0.11	--	33.4
Estuary	0.03	--	--	--	0.10	--	34.[illegible]
Coastal							
Haines 1979							
Coastal Shelf Waters, Georgia 0-10 km from Shore	0.007	--	--	--	0.16	--	24.4
Butler 1979							
English Channel	--	4.0	0.36	0.55	--	--	--

and north shore tributaries resembled river input from the Santee River, North Carolina, Kaneohoe Bay, Hawaii, the lower reaches of the Tamar Estuary, Great Britain, and Barataria Bay, Louisiana (Table 2). In contrast, the southern Lake Pontchartrain wetland tributaries (Walker Canal) showed high values for inorganic nitrogen; they were in the range of both natural and channelized streams in North Carolina and the freshwater portion of the Barataria Basin, Louisiana. These later comparisons were the higher concentrations in each estuarine system. Total organic nitrogen in Lake Pontchartrain ranged between that found in both natural and channelized streams in North Carolina. Total organic nitrogen in the Tamar Estuary was much lower than in the Lake Pontchartrain stations. The southwest wetland tributaries of Lake Pontchartrain resembled the high TON concentrations in the freshwater portions of the Barataria Basin, Louisiana.

Total phosphorus concentration in Lake Pontchartrain were similar to the natural streams in North Carolina, the freshwater portion of the Rappahannock Estuary, and estuarine waters of Barataria Bay, Louisiana. The higher total phosphorus concentrations in the southern wetland tributaries were much like the freshwater portion of the Barataria Basin. Similarly, concentration of lake chlorophyll _a_ was similar to concentrations in estuarine Barataria Bay. Chlorophyll _a_ concentrations in southern waterways ranged between those found in the freshwater portion of the Barataria Basin.

The above comparisons between Lake Pontchartrain stations and other estuarine systems suggest that none of the lake stations are highly enriched except for those in the southwestern corner of the lake (St. Charles

Parish). These tributaries are very similar to the eutrophic freshwater portion of the Barataria Basin, Louisiana. The north shore and the lake contained concentrations within the range measured in Barataria Bay, a coastal embayment.

Quantifying Water Quality

The foregoing comparison of Lake Pontchartrain with other areas indicates that there is a range of water quality conditions in the lake and surrounding tributaries. This range encompasses reported trophic states from oligotrophic to eutrophic. To further quantify these water quality conditions, we calculated a trophic state index (TSI) for the lake.

The Barataria TSI was modeled after Brezonik and Shannon's (1971) trophic state analysis of 55 Florida lakes. The degree of eutrophication or enrichment was quantified by using the multivariate statistical techniques of cluster and principal component analyses. Seven trophic state parameters comprised the Florida index: total organic nitrogen, total phosphorus, Secchi disc depth, chlorophyll _a_, primary productivity, conductivity, and Pearsall's cation ration (CA+Mg/K+Na).

The TSI developed for the Barataria Basin, Louisiana, was composed of four variables: total organic nitrogen, total phosphorus, Secchi disc depth, and chlorophyll _a_ (Craig et al. 1978; Seaton and Day 1979; Seaton 1979; Witzig and Day, in preparation). Two of the Florida variables, conductivity and Pearsall's cation ratio, were deleted because they are inappropriate for estuarine waters.

Primary productivity was not available for the Barataria TSI. However, a comparison of primary production in the few stations measured

in independent studies and their respective TSI scores produced a regression coefficient of 0.80. The Lake Pontchartrain stations were included in the regression analysis.

The applicability of the Barataria TSI to other Louisiana coastal waters was tested with water chemistry data from Lake Pontchartrain (Witzig and Day, in preparation). The four master stations from Dow and Turner's (Chapter 7) and Cramer's (1978) transect studies along the southwestern lakeshore were tested. The TSI values for these stations are shown in Tables 3 and 4.

TSI scores for tributaries of Lake Pontchartrain (Table 4) fell both within the range of eutrophic stations and outside the range of the hypereutrophic stations within the Barataria Basin (Table 5). The TSI scores for the open lake stations (Table 3) fell outside the lower range of scores calculated for the Barataria Basin (Table 5). Comparison of nutrient concentrations show values similar to those measured at Caminada Pass and thus are characteristic of Gulf of Mexico waters (Seaton 1979).

The 55 lakes analyzed by Brezonik and Shannon (1971) ranged from ultra-oligotrophic by hypereutrophic. The large range of trophic states provided a broad spectrum for quantitative comparisons. Except for salinity, many of the Florida lakes resembled Louisiana waters. Brezonik's data were recalculated according to the Barataria TSI. This recalculation resulted in a much broader scale of trophic states for comparison with Louisiana waters. Brezonik and Shannon's TSI ranking of Florida waterbodies and those recalculated from the Barataria analyses were compared using Spearman's rank correlation test. The new ranking of Florida waterbodies by the Barataria TSI showed a 95% correlation with the original ranking by Brezonik and Shannon (1971). However, discrepancies occurred between the oligotrophic and lower mesotrophic range (Table 6).

Table 3. Lake Pontchartrain, LA, Trophic Classification of Master Stations from Dow and Turner, Chapter 7

Master Stations	Score	Trophic Group*
1 Pass Manchac	-5.2	M-O
2 Mid-Lake	-5.5	M-O
3 IHNC	-6.3	M-O
4 The Rigolets	-6.2	M-O

*M-O Meso-oligotrophic

Table 4. Lake Pontchartrain, LA, Trophic Classification of Stations from Cramer (1978)

Station #	Location	Score	Trophic Group*
Transect 1:			
A1-5	Crossbayou Canal	26.7	H
A6-10	Bayou LaBranche	17.6	H
C1-5	Offshore Swamp	- 3.4	M
Transect 2:			
B1-5	Walker Canal	1.4	E
B6-10	Bayou Piquant	0.6	E
C6-10	Offshore Marsh	- 0.9	M

*M Mesotrophic
E Eutrophic
H Hypereutrophic

Table 5. Trophic State Classification of Barataria Basin, LA (Seaton 1979)

Sta. No.	Name	Trophic State	Waterbodies classification
25	Caminada Pass	-4.8	M-O
17	Bayou Rigolettes	-4.3	M
24	Barataria Bay	-3.8	M
12	Lake Salvador	-3.3	M
18	Bayou Perot	-2.8	M
21	Little Lake	-2.7	M
16	Bayou Barataria	-1.8	M
23	Barataria Waterway	-1.6	M
3	Natural Swamp Stream	-1.4	M
22	John-the-Fool Bayou	- .6	M
20	Oil and Gas Field	- .4	M
4	Bayou Chevreuil	.6	E
8	Recreational Canal	.7	E
13	Lake Cataouatche	.7	E
11	Bayou des Allemands	.9	E
14	Bayou Segnette	1.6	E
15	Gulf Intracoastal Waterway	2.1	E
9	Bayou des Allemands	2.6	E
10	Burtchell Canal	2.7	E
1	Bayou Citamon	3.7	E-H
7	Lac des Allemands	3.8	E-H
6	Bayou Chevreuil	4.0	E-H
5	St. James Canal	6.4	H

Table 6. Reclassification of 55 Florida Lakes According to Four Variable Trophic State Analyses

Lake	No.	Score	Trophic Group
Santa Roas	47	-31.9	UO
Cowpen	54	-25.1	UO
Kingsley	40	-24.9	UO
McClous	49	-24.8	UO
Brooklyn	43	-23.1	UO
Long	52	-22.8	UO
Magnolia	42	-20.4	UO
Anderson-Cue	50	-20.0	UO
Gallillee	55	-18.9	UO
Sandhill	41	-18.8	UO
Swan	45	-18.1	UO
Winnett	53	-17.8	O
Geneva	44	-17.3	UC
Santa Fe	1	-13.2	O
Clearwater	7	-12.5	O
Meta	21	-12.1	M
Still Pond	13	-11.8	UO
Weir	39	-10.8	M
Hickory Pond	3	-10.0	O
Bevilles Pond	26	- 9.7	M
Little Santa Fe	2	- 9.3	O
Unnamed	25	- 9.1	M
Altho	4	- 8.7	O
Wall	46	- 8.4	O
Moss Lee	11	- 8.1	O
Unnamed	10	- 7.7	M
Suggs	51	- 6.3	O
Palatka	16	- 6.1	M
Adaho	48	- 6.0	O
Watermelon Pond	29	- 5.6	M
Long Pond	30	- 5.5	O
Harris	36	- 5.1	M
Jeggord	12	- 5.1	O
Orange	15	- 4.7	M
Elizabeth	6	- 4.3	M
Little Orange	9	- 4.3	M
Lochloosa	14	- 2.9	M
Unnamed	27	- 1.9	M
Cooter Pond	5	- 1.5	M
Tuscawilla	33	- 0.9	M
Mize	18	- 0.9	M
Calf Pond	19	- 0.1	M
Wauberg	32	0.4	E
Eustis	37	1.0	E
Newnan's	17	1.2	E
Hawthorne	8	1.5	E
Clear	24	3.1	E

Table 6. (Continued)

Lake	No.	Score	Trophic Group
Griffen	38	4.1	H
Alice	22	5.2	H
Burnt Pond	31	6.2	E
Kanapaha	28	8.4	H
Bivin's Arm	23	9.7	H
Dora	35	10.4	H
Unnamed	20	11.6	H
Apopka	34	13.9	H

Using the recalculated values, the four master stations of Lake Pontchartrain were classified in the lower mesotrophic-oligotrophic range of the trophic state spectrum (Dow and Turner, Chapter 7; Table 3). This classification agrees with the earlier comparisons of concentrations in other estuarine systems (Table 2). Given the available data, this is the most accurate classification. In addition, the earlier transect studies from Cramer (1978) ranged between mesotrophic to hypereutrophic waters (Table 4).

CONCLUSIONS

We compared nutrient concentrations in Lake Pontchartrain with those in other estuaries. We also compared the TSI calculations on Lake Pontchartrain data with those of other estuaries. On the basis of these data, we conclude:

1) The open waters of Lake Pontchartrain are in the lower mesotrophic to oligotrophic range.

2) Tributary waters receiving significant upland runoff are eutrophic.

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AD-A123 375 ENVIRONMENTAL ANALYSIS OF LAKE PONTCHARTRAIN LOUISIANA ITS SURROUNDING WE..(U) LOUISIANA STATE UNIV BATON ROUGE COASTAL ECOLOGY LAB J H STONE FEB 80 2/7

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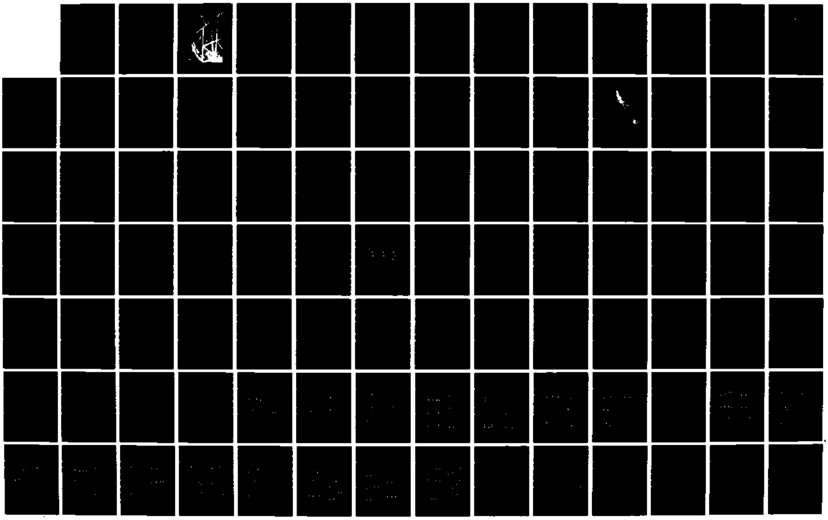

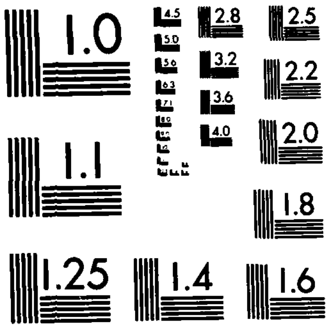

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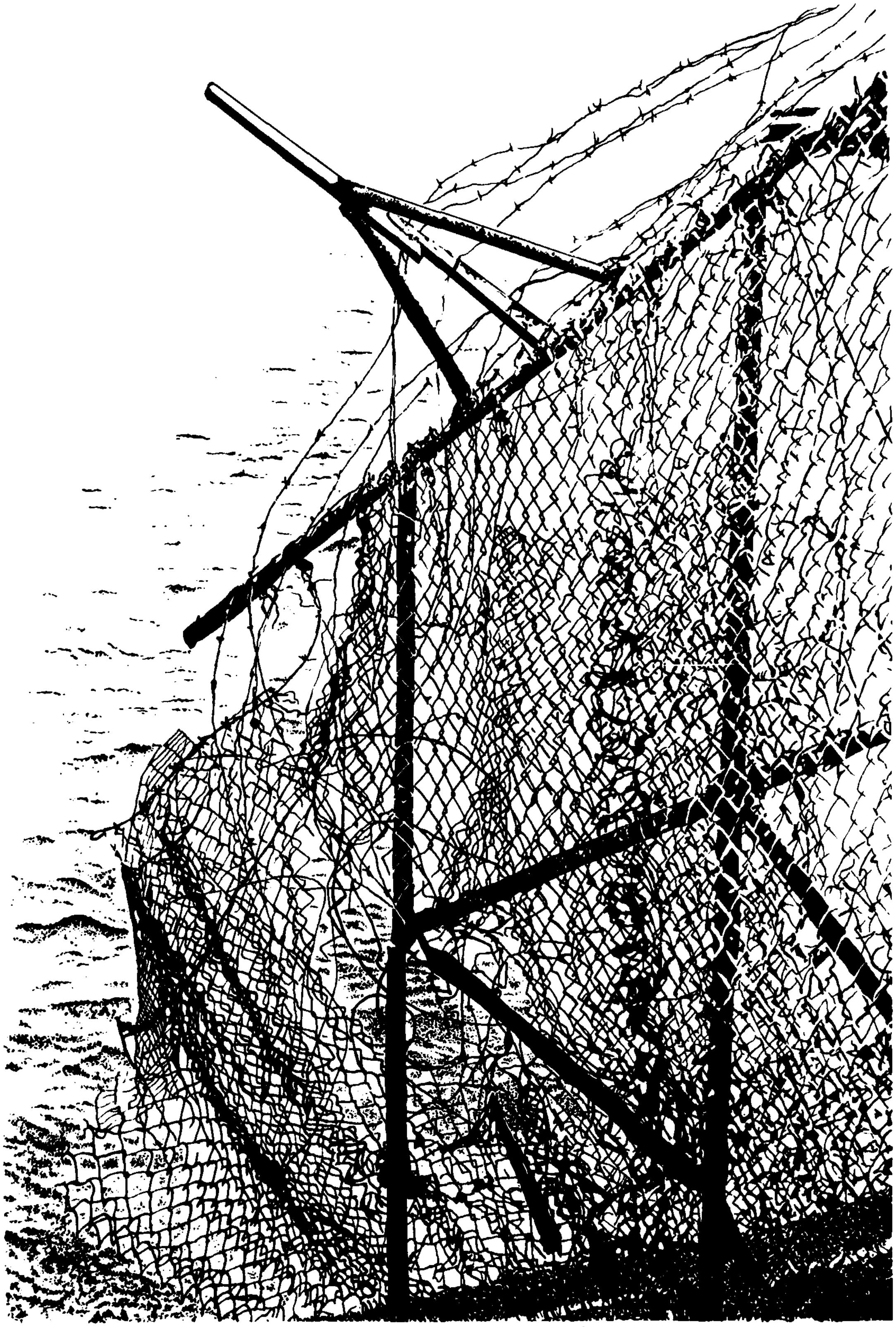

Fence along the south shore near the amusement park

Chapter 3

COMPUTATION OF DRIFT PATTERNS IN LAKE PONTCHARTRAIN, LOUISIANA

by

B. T. Gael

ABSTRACT

Circulation and drift patterns in Lake Pontchartrain were studied by means of a numerical computation. The resultant data suggest that wind is the most important driving force for net drift in the lake, and that this net drift is generally with the wind in shallow nearshore water and counter to the wind in the deeper water or mid-lake.

INTRODUCTION

Estuarine water motions are generated by a number of oceanic, riverine, and atmospheric forces combined with topographic controls. Circulation, in turn, influences the distribution of chemical and biological species in the estuary. Consequently, descriptions of these estuarine water motions are of fundamental importance to coastal ecology.

The objective of this study was to investigate wind-driven circulation in Lake Pontchartrain using modern computational methods. The scope of this study was limited, however, to generalized results and was intended to indicate trends rather than to provide quantitative predictions. In this context, the results were extremely useful for locating suitable sites for biological, chemical, and physical sampling and for interpreting the data.

METHODS

Circulation Analysis Finite Element, 1-layered (CAFE-1), a depth-integrated, two-dimensional, finite element, hydrodynamic-numerical model (Wang and Connor 1975), was used to estimate drift patterns in Lake Pontchartrain. CAFE-1 was originally developed at Massachusetts Institute of Technology and has been verified for a number of coastal circulation studies (Connor and Wang 1973; Celikkol and Reichard 1976; Swakon and Wang 1977). The software for this study (the University of Miami version) was unmodified. Application of the software to the particular case of Lake Pontchartrain was consistent with procedures outlined by the model's authors (Wang, pers. comm. 1978). Setting up CAFE-1 for Lake Pontchartrain entailed the following procedure. The area of the lake was divided into a finite number of triangular elements; the vertices of each element being a node (Fig. 1); spatial resolution was made finer along the nearshore zone and near tidal passes where velocity gradients were assumed to be strongest. Data on the following parameters were assembled: (a) location of each node, (b) mean low water depth at each node, (c) bottom friction and eddy viscosity coefficient at each node, (d) latitude (for Coriolis parameter), (e) tidal period, (f) water density, (g) tidal amplitude and phase along open boundaries, (h) speed and direction of wind over time, and (i) initial conditions of height and volume flux at each node. Lake geometry and depths used in the model were determined from a National Ocean Survey map (no. 11369).

Normal boundary angles were calculated from an algorithm provided by Dr. Wang. Manning friction coefficients were between 0.018-0.022

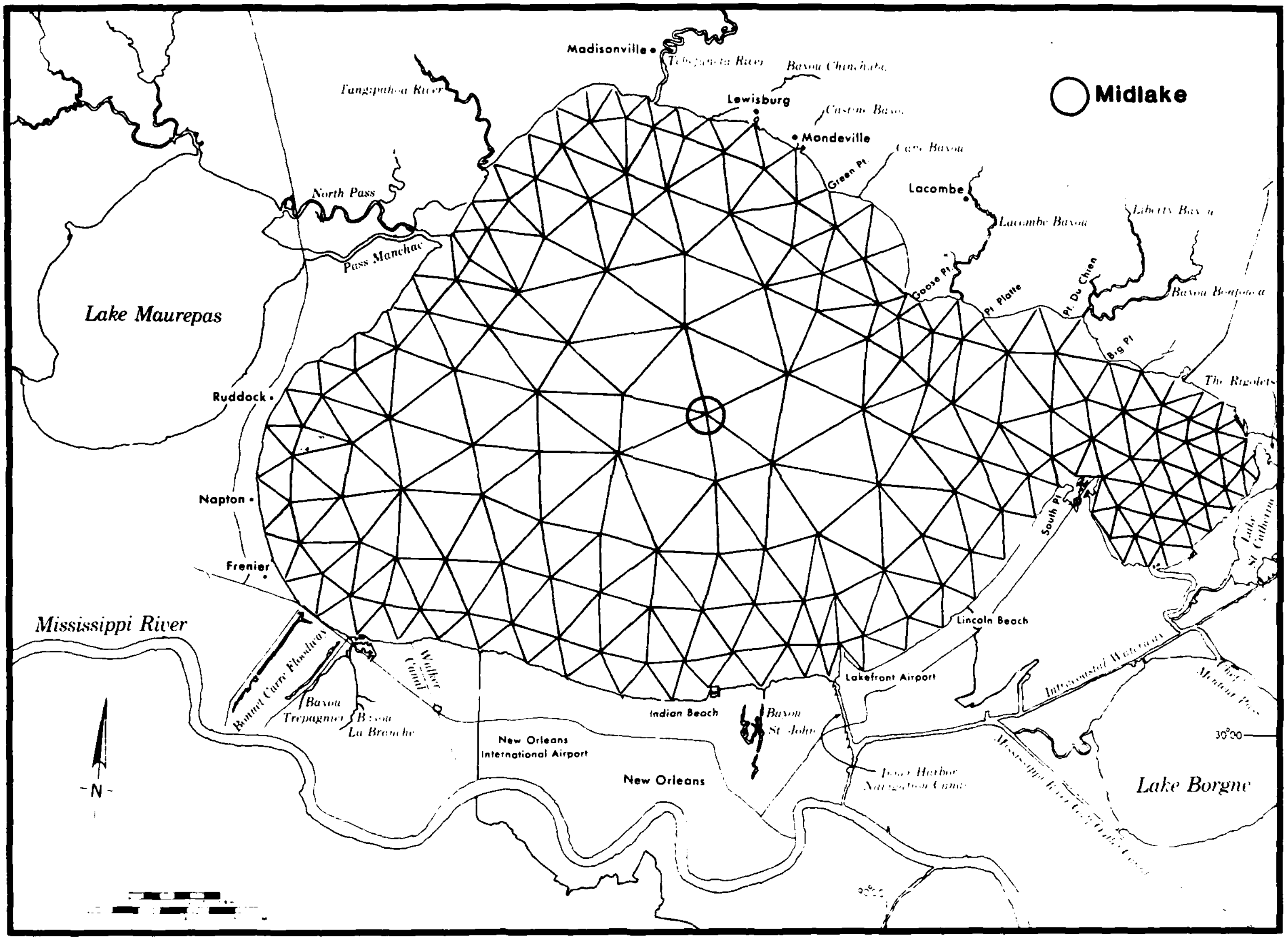

Figure 1. Location of nodes used by the CAFE-1 model. The center node is indicated by a circle. Each node was characterized by a set of data described in the text.

pass so that net flow through the system was zero and each pass still bore its proportion of tidal flow.

Computational runs were made for four cases. Three (Cases 1 through 3) were typical of the warmer months of the year, and the fourth (Case 4) was typical of fall and early winter. In each case, a typical wind speed and direction, a typical river discharge, and the average tidal prism (240 million m^3/diurnal cycle) was imposed on the lake. The model was allowed to equilibrate for 36 hours (simulation time) to this regime before data were recorded.

RESULTS

Initial sensitivity analyses on the model showed the importance of wind forcing on the system. For example, if the river discharges of less than 10,000 cfs at Pass Manchac forced the model (no wind or tidal forcing), then negligible currents were generated in the center of the lake.

In addition, average tidal fluxes of 240 million m^3/diurnal cycle without wind or river discharge produced net speeds (averaged over several tidal cycles) of only a few cm/sec, but this effect disappeared west of a north/south line through Goose Point. In contrast, even light winds of 2 m/sec produced net circulation over the whole lake. This circulation organized into a pattern showing water drifting with the wind nearshore and returning against the wind in the middle of the lake. Wind forcing, then, was more significant than the average effect from either river discharge or tidal flux for net water drift.

Four distinct cases were investigated:

Case 1: Mean tidal prism was 240 million m^3/diurnal cycle; wind was from southeast at 7 m/s; river discharge was 50,000 cfs net from Pass Manchac.

Case 2: Mean tidal prism was 240 million m^3/diurnal cycle; wind was from southeast at 6.0 m/s; river discharge was 50,000 cfs at Pass Manchac and 200,000 cfs at Bonnet Carre Floodway.

Case 3: Mean tidal prism was 240 million m^3/diurnal cycle; wind was from southeast at 5 m/s; river discharge was negligible.

Case 4: Mean tidal prism was 240 million m^3/diurnal cycle; wind was from northeast at 6 m/s; river discharge was negligible.

These four cases occur with significant frequency, particularly Case 3, during the ecologically important period of March through October.

Figure 2 shows the circulation calculated for a frequent condition in April and May (Case 1) in which winds are strong from the southeast and river discharge is nearly maximum. Highest velocities are near the passes and at the west end of the lake near Frenier. Both north and south shores show water drifting to the west, with the speed and direction apparently independent of tidal cycle. During ebb tide there is a band of easterly flowing water through the lake's center counter to the littoral drift. Figure 3 shows the net drift pattern of these conditions for two tidal cycles.

Figure 4 shows the calculated circulation for spring with the addition of water from the Bonnet Carre Floodway (Case 2). A different circulation pattern results, in that the longshore, wind-driven currents are suppressed, and waters from Bonnet Carre flow directly through the

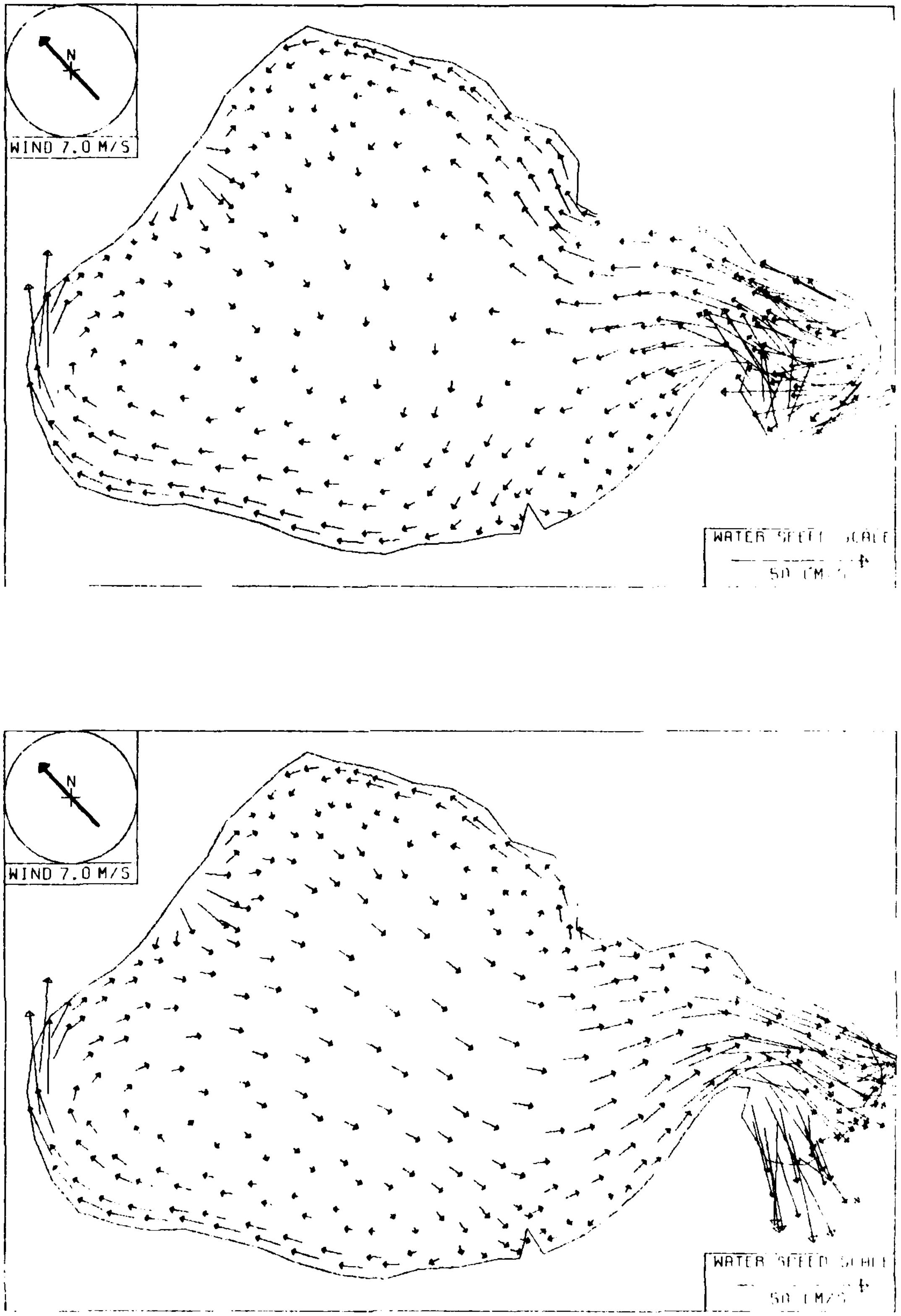

Figure 2. Depth-integrated circulation in Lake Pontchartrain, LA, during spring conditions of high river discharge and a southeast wind. The top figure shows incoming tide and the bottom figure shows outgoing tide.

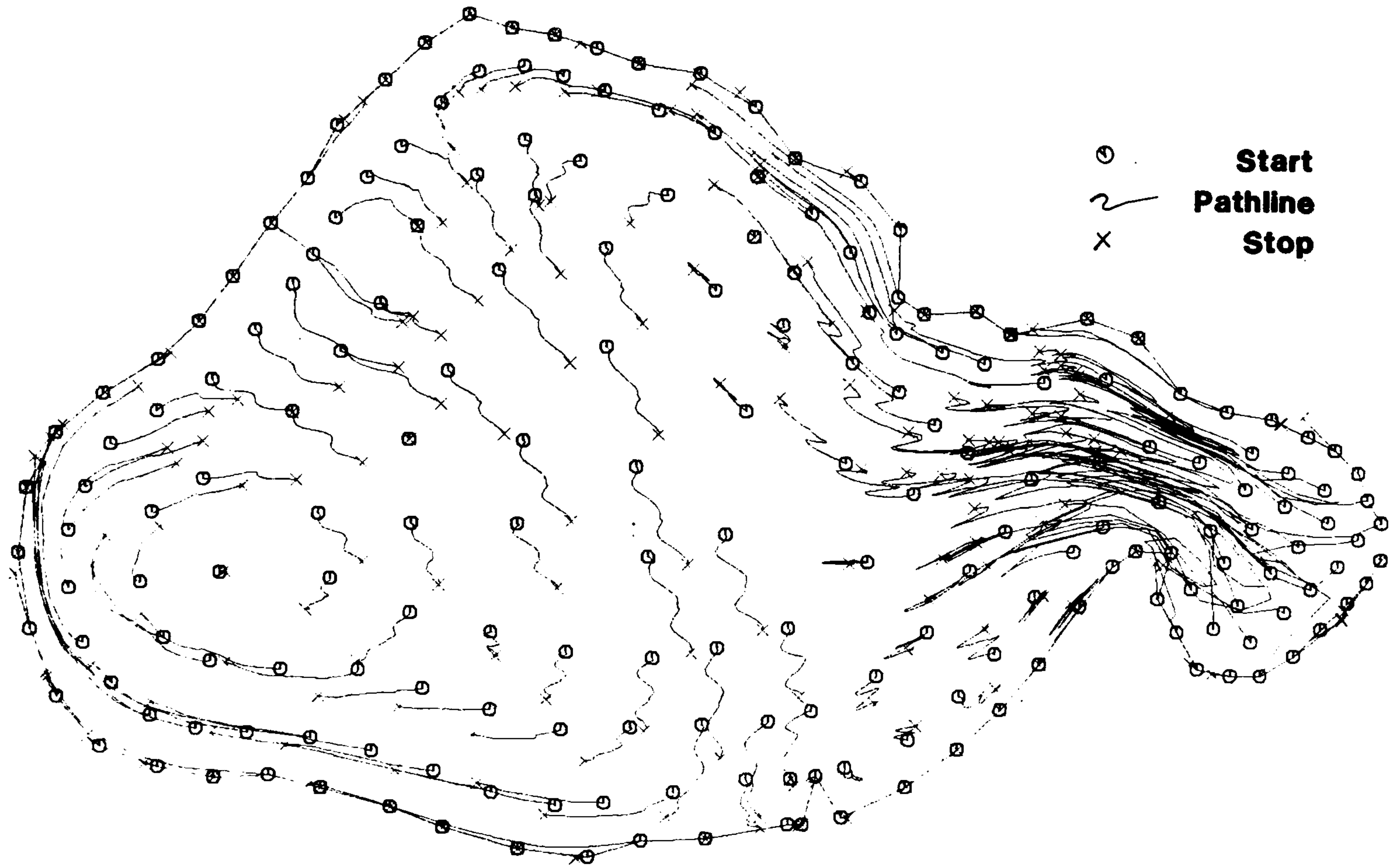

Figure 3. Drift pattern for conditions indicated on Figure 2.

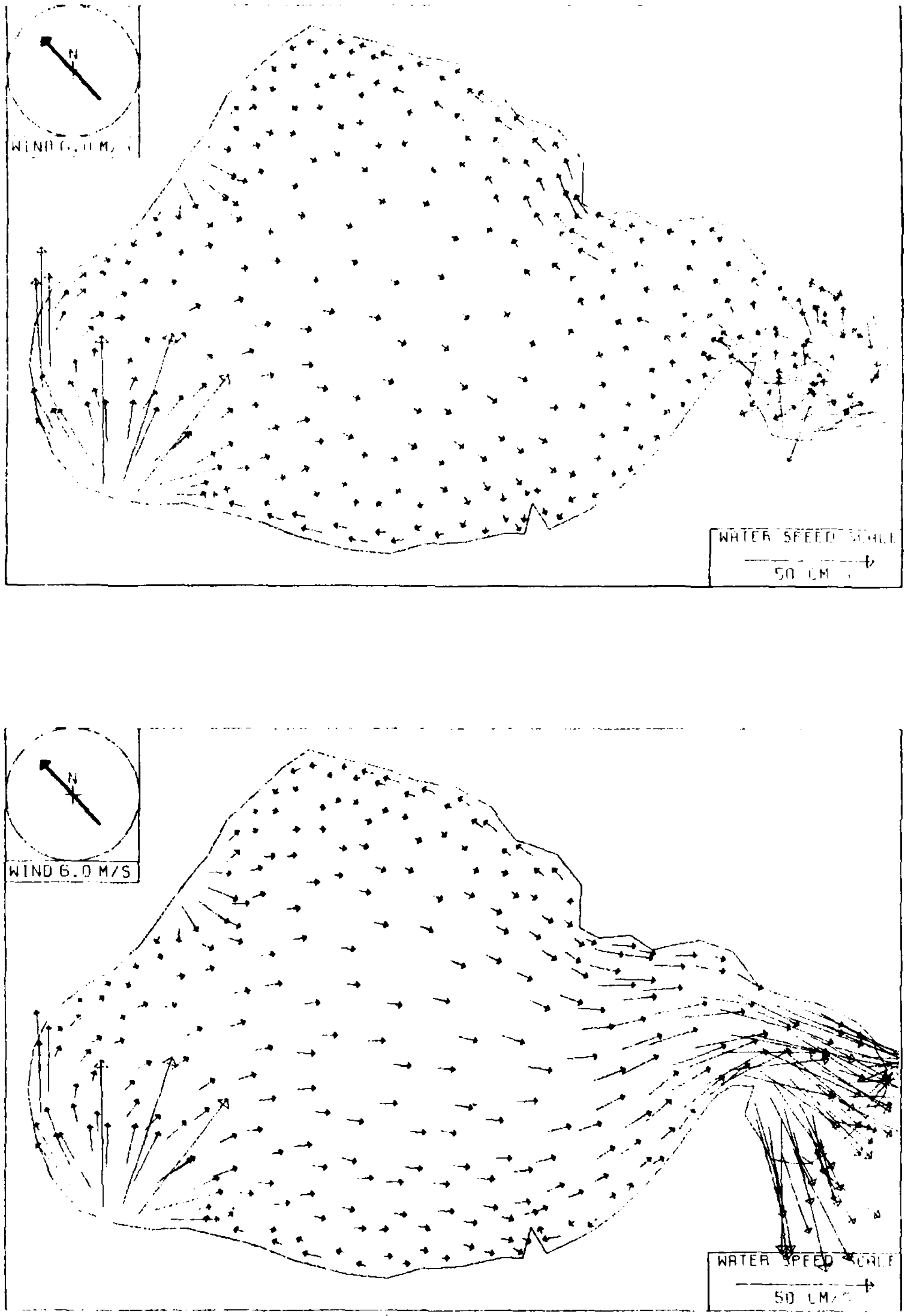

Figure 4. Depth-integrated circulation in Lake Pontchartrain, LA, during spring conditions, plus Bonnet Carre Floodway at 70% of maximum. The top figure shows incoming tide and the bottom figure shows outgoing tide.

lake center and near the south shore (see also Swenson, Chapter 4). The net drift pattern for these conditions is shown in Figure 5 for two tidal cycles.

Figure 6 shows the calculated circulation in Lake Pontchartrain driven by a steady, uniform wind field from the southeast at 5 meters per second (Case 3). The flow through the open tidal boundaries was set to approximate the mean astronomical tidal prism for a diurnal tide. Flow through the open boundary at Pass Manchac was prescribed s h that the diurnal average approximated 200 m^3/sec into the lake. Th driving conditions could be considered typical for June, July, and Aug . Figure 6 shows circulation conditions at minimum ebb for the " al" summer conditions and at maximum flood. The ebbing circulation was dominated by two large gyrals in the middle of the lake, with windward drift at the north and south shores. At maximum flood, the westward littoral drift was still present but the return flow through the lake center was much reduced and not as clearly demarked. Figure 7 shows the path of drifting water particles over two days of typical summer conditions. Extrapolation of these data suggest it would take over 45 days for a particle to complete the entire western gyral cycle.

Figure 8 shows simulated lake circulation for steady, uniform northeast wind at 6 meters per second. Tidal and river flows approximated the annual mean values. This combination of driving functions was intended to represent conditions typical of September and October (or fall and early winter). Circulation through the main body of the lake was counterclockwise, with strong littoral drift along the western shore. Drift along the northern and southern shores was still westward,

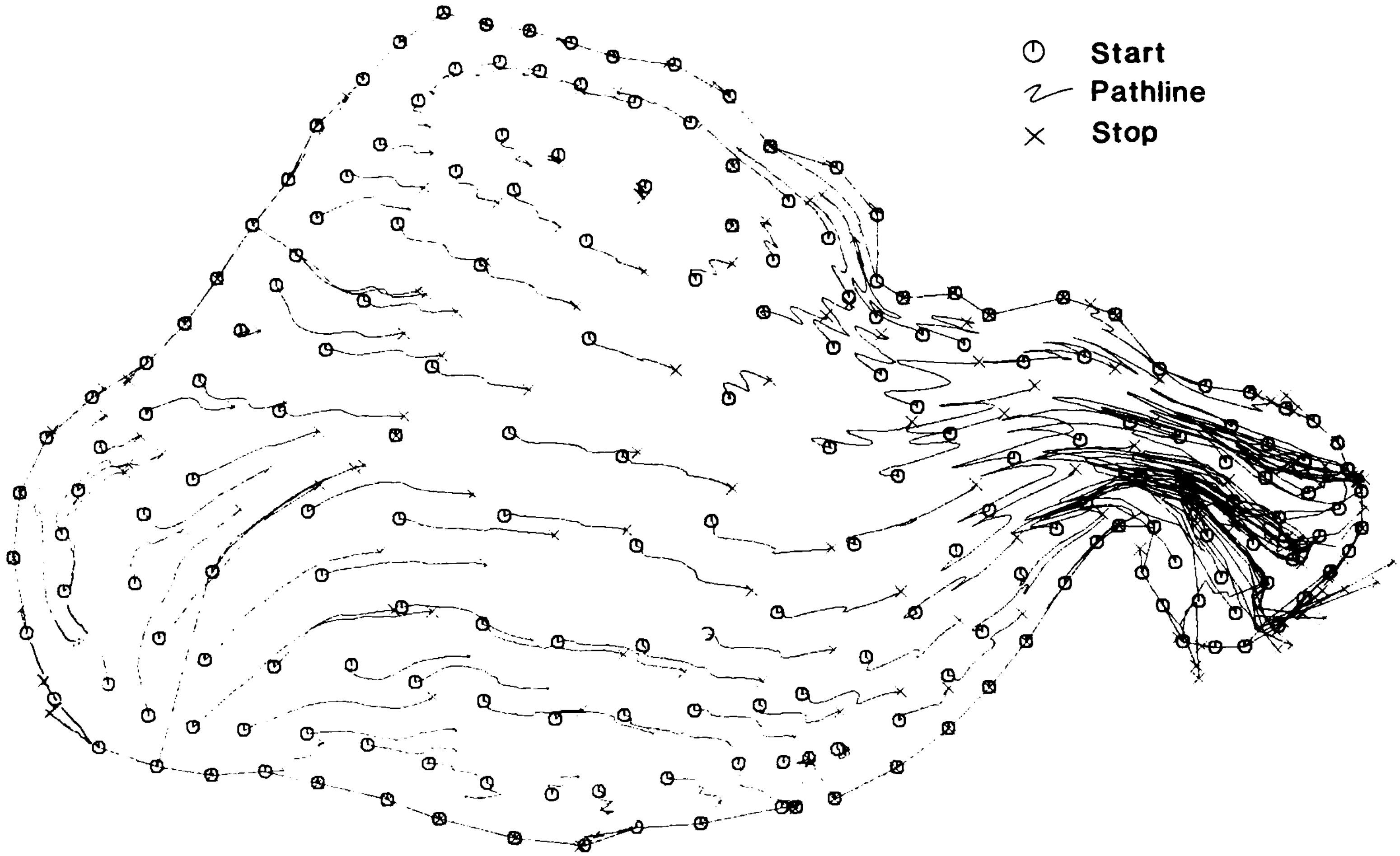

Figure 5. Drift pattern for conditions indicated on Figure 4.

Figure 6. Depth-integrated circulation in Lake Pontchartrain, LA. Summer conditions: low wind and low river runoff. The top figure shows incoming tide; the bottom, outgoing tide.

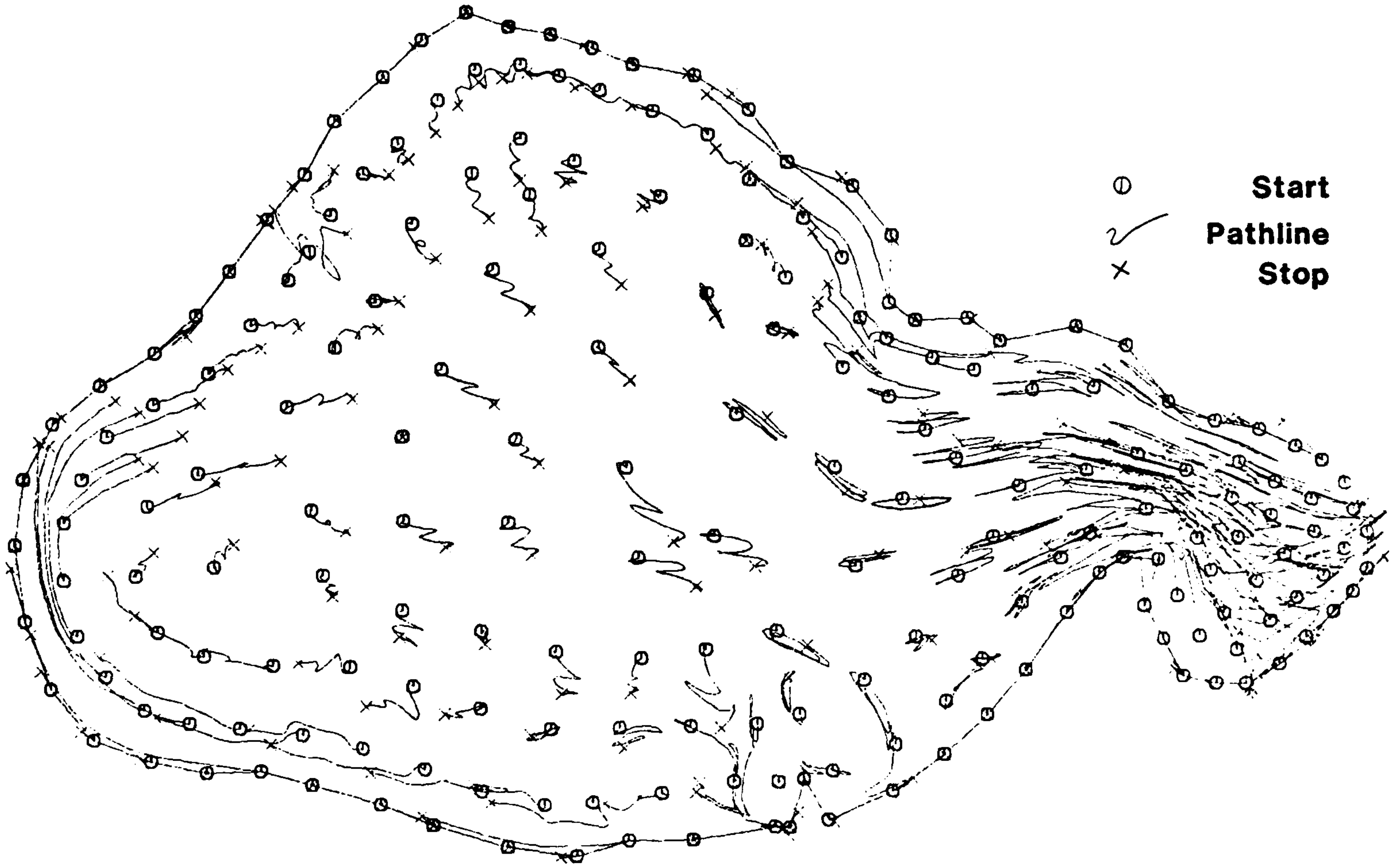

Figure 7. Drift patterns for conditions indicated in Figure 6.

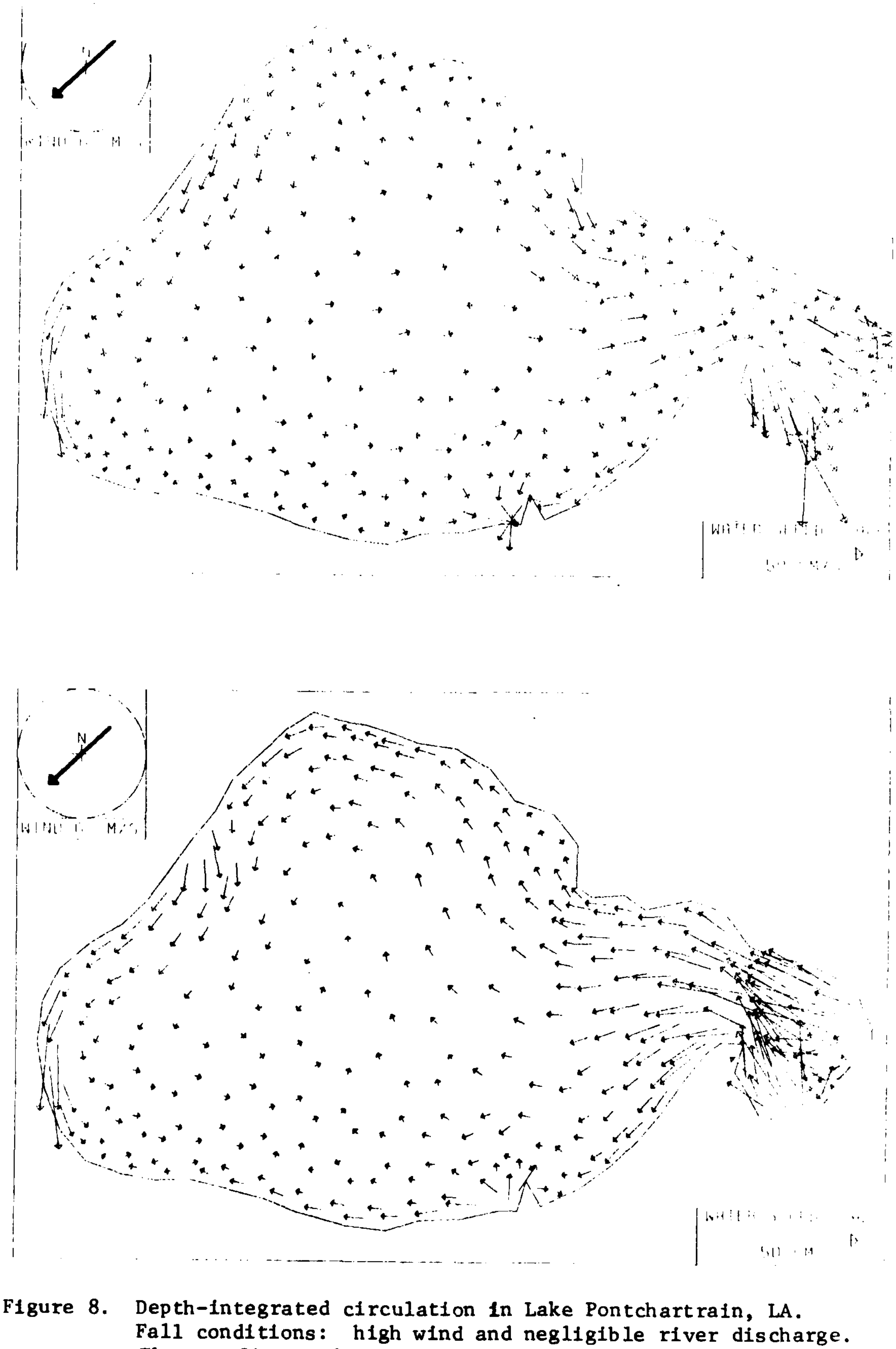

Figure 8. Depth-integrated circulation in Lake Pontchartrain, LA.
Fall conditions: high wind and negligible river discharge.
The top figure shows incoming tide; the bottom, outgoing tide.

throughout the lake. Eddy viscosity coefficients were constant for all elements throughout the lake and were set to 20 m^2/s. However, results were not sensitive to values as high as 100 m^2/s or to as low as 5 m^2/s.

Wind forcing was modeled as a steady, uniform field over the entire lake. CAFE-1 calculates the drag coefficient for wind as directly proportional to wind speed. In accordance with our objective of generalized drift patterns, average seasonal values of wind speed and direction were calculated from meteorologic data of U.S. Weather Bureau at Moisant Airport, New Orleans (1963-1973).

Tidal fluxes over the open boundaries were driven by tidal heights at the open boundary nodes. Tidal heights used to drive the model were typical tidal signals taken or extrapolated from nearest gages. Open boundary nodes of The Rigolets were very near a tide gage, whereas open nodes at Chef Menteur Pass were several miles from gaged data. Tidal heights for Pass Manchac and Inner Harbor Navigation Canal (IHNC) could only be approximated. Depths of open boundary nodes were artificially adjusted so that proper mass flux was generated through the passes for a given tidal range cycle. Tidal transport and range estimates were taken from COE (1962) and from available tidal gage data. The phase lags of the tidal wave were made relative to The Rigolets and were estimated to be 0 to 1.5 hours at Chef Menteur Pass, 1.5 to 3.0 hours at IHNC, and 5.0 to 6.0 hours at Pass Manchac. Tidal flux was 240 million m^3 per cycle for the average diurnal tide, of which about 50% flowed through The Rigolets. Since only steady state was considered in this study, net flux through the system was required to be zero. For example, when wind tilted the entire lake surface, mean water levels were adjusted at each

but the width of this drifting water was much smaller than in previous runs. By extrapolation of net drift data in Figure 9, circulation time for the complete counterclockwise gyre was about one month.

DISCUSSION

Two small field studies were conducted to compare the calculated drift patterns with those observed in the field. Dye and drogue surveys were carried out August 14-15, 1978, in the eastern end of the lake. Nearshore drift patterns between Bayou Lacombe and Goose Point indicated a consistent westward component of low speed (<5 cm/sec) while winds were from the southeast. This pattern was observed on numerous occasions by other field personnel. Data collected along a transect 1 mile from and parallel to I-10 during a rising tide showed currents 15-30 cm/sec, higher near Point Aux Herbes. These field data are consistent with the results shown in Figure 7.

Another survey was conducted on January 9, 1979, at the west end of the lake. Dye injections showed a southeastward longshore velocity of 20-25 cm/sec near Ruddock, which decreased in strength toward Frenier. Further offshore from Frenier, currents exhibited low velocities and were moving away from shore toward the northeast. Prior to and during this survey, winds were out of the northeast at 4-6 m/sec. Figure 9 shows simulated results for 6 m/sec from northeast.

The two small field studies corroborated some of the results of the computational effort and indicate data output from CAFE-1 approximated the circulation pattern in Lake Pontchartrain.

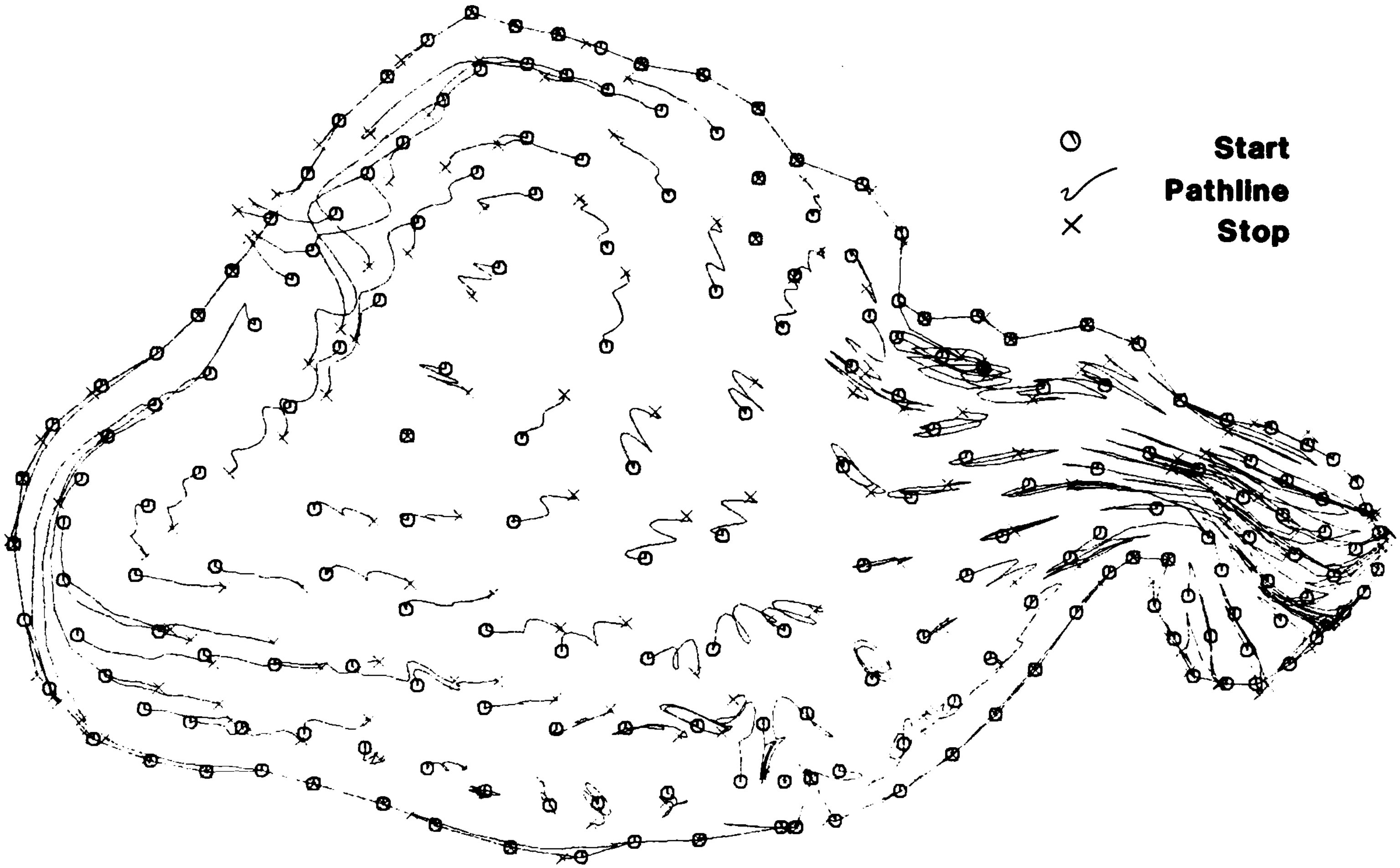

Figure 9. Drift patterns for conditions indicated in Figure 8.

CONCLUSIONS

The general conclusions of this study are:

1) Wind appears to be the most important force driving net water motion over Lake Pontchartrain.

2) The general circulation pattern in the lake appears similar to coastal jetting where water nearshore moves with the wind and counterflow develops through deep waters in the lake's center.

3) Overall drift in Lake Pontchartrain is slow, generally less than 10 cm/sec in the lake, but considerably higher nearer the tidal passes.

These conclusions indicate that future circulation field studies should employ very sensitive speed and direction equipment in the lake to adequately verify a more detailed model.

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Chapter 4

GENERAL HYDROGRAPHY OF LAKE PONTCHARTRAIN, LOUISIANA

by

Erick M. Swenson

ABSTRACT

Currents, conductivity, and temperature profiles were measured at various locations throughout Lake Pontchartrain during 1977-1979. Conductivity and temperature maps were constructed from a shipboard flow-thru conductivity and temperature system.

Current speed data indicate an average lake speed of 12-14 cm/sec. Neither the current data nor the conductivity and temperature data indicates a strong vertical stratification. Instead, the lake appears to have a horizontal stratification that is controlled by the transfer of water through the tidal passes.

Wind speed and wave height data indicate that conditions favorable to bottom sediment resuspension occur approximately 15% of the time.

Tidal height data were used to determine marsh flooding statistics. These data indicate that peaks in marsh flooding (hours of flooding) occur in the spring and the fall and correspond with peaks in the mean lake level.

INTROUDCTION

Lake Pontchartrain does not fit Cameron and Pritchard's (1963) definition of an estuary: "an estuary is a semi-enclosed coastal body of water which has free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage." Lake Pontchartrain does not have "free connection" with the open sea as do estuaries such as Chesapeake and Galveston Bays; instead, it has a restricted connection to Lake Borgne. Thus, Pontchartrain represents a system with a restricted connection to another estuary as opposed to a "free-connection with the open sea." Following Officer (1976), Lake Pontchartrain can be considered as an "associated water-body" to an estuary. This category is a catchall for systems such as straits, canals, bays, lagoons, and seas with restricted access.

The Lake Pontchartrain system has several driving forces that determine its overall circulation pattern. They are: tides, winds, and streamflow. Each is discussed below.

The lake has a diurnal tide with a mean range of about 12 cm (Outlaw 1979). This tidal signal produces barotropic slopes on the order of 10^{-6} radians, which is comparable to barotropic slopes determined by Kjerfve (1973) in Caminada Bay, a shallow, bar-built Louisiana estuary. The tidal prism volume was calculated to be approximately $3 \times 10^8 m^3$.

Another force, the wind, can be a dominant factor in controlling the circulation. Tidal data from the lake (U.S. Army Corps of Engineers [COE] 1962) indicate wind-induced slopes can be on the order of 10^{-6} to 10^{-5} radians. Figure 1 (based on data from Stone et al. 1972) demonstrates that the wind can control the circulation. The figure indicates

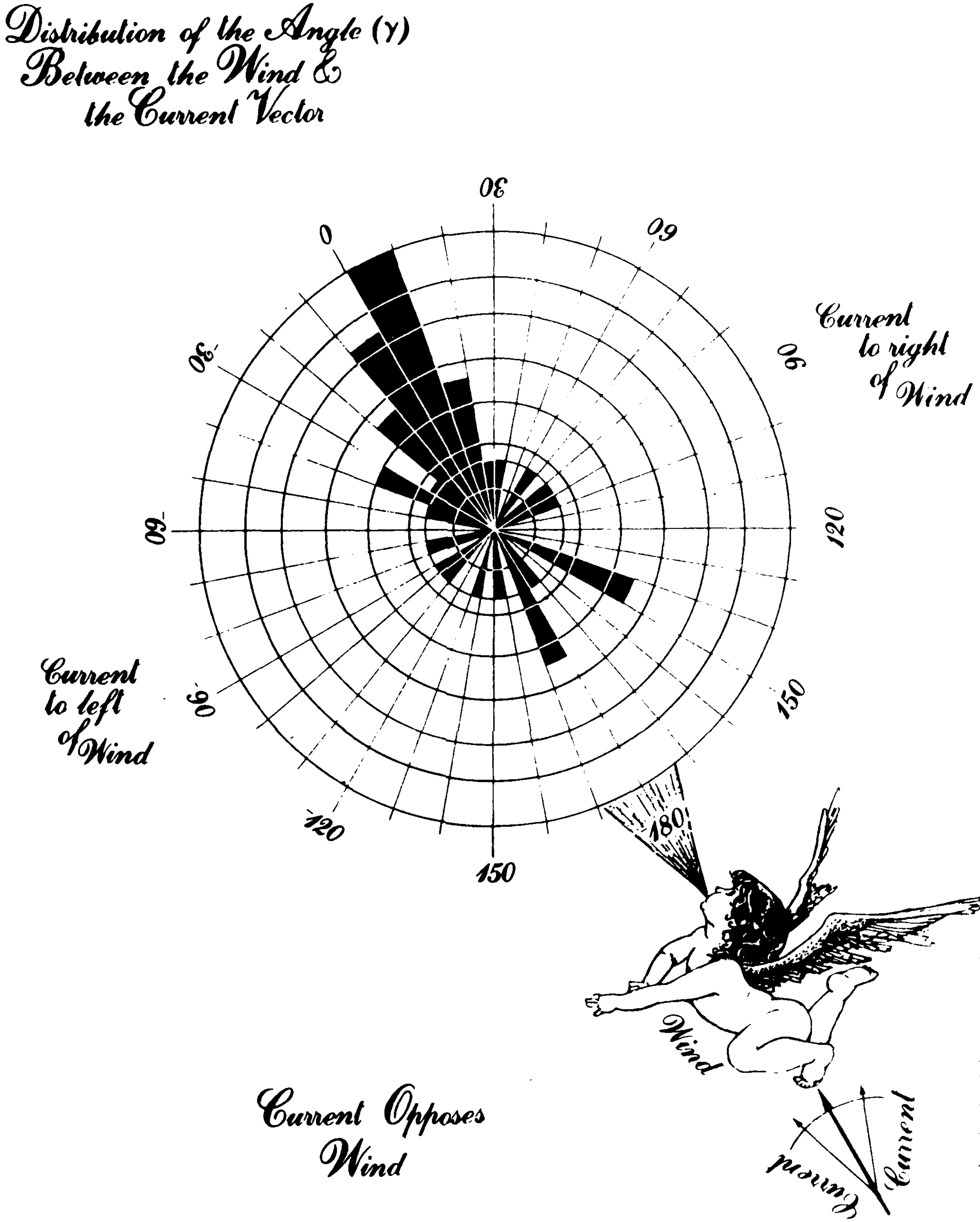


Figure 1. Circular histogram showing distribution of the angle between wind direction and current direction in Lake Pontchartrain. Each concentric ring corresponds to 2% with zero at the center. An angle of 0 indicates the wind is behind the current (Based on data from Stone et al. 1972).

that the majority of the current directions are related to the wind, with the wind coming from the quadrant behind the current.

The rivers around the lake can also be important forces. Under flood conditions, they can supply a volume of water that may equal or exceed the tidal prism volume. In the Lake Pontchartrain system, all of the variables under study (e.g., tides, winds, runoff, nutrients) are continually changing. Hence, the estuary may be always trying to reach a balance that it probably never achieves. As Dyer (1973) points out, one cannot be sure if one is observing general principles or unique details.

MATERIALS AND METHODS

From December 1977 to March 1979, a study was conducted that involved both the collection of field data and the compilation of historical data on the Lake Pontchartrain hydrographic system. This study included descriptions of the lake currents, conductivity and temperature patterns, as well as other environmental parameters (air temperature, rainfall, streamflow, winds, and waves). The main objective of this report is to give a descriptive picture of the general hydrography of the lake.

The field program consisted of the establishment of 18 stations (14 survey stations and 4 master stations) throughout the lake and a number of survey cruises during which a flow-thru system was used to measure salinity and temperature.

A map showing the station locations and the survey track is presented in Figure 2. Table 1 gives the dates of each cruise and comments on the type of data collected.

A

B

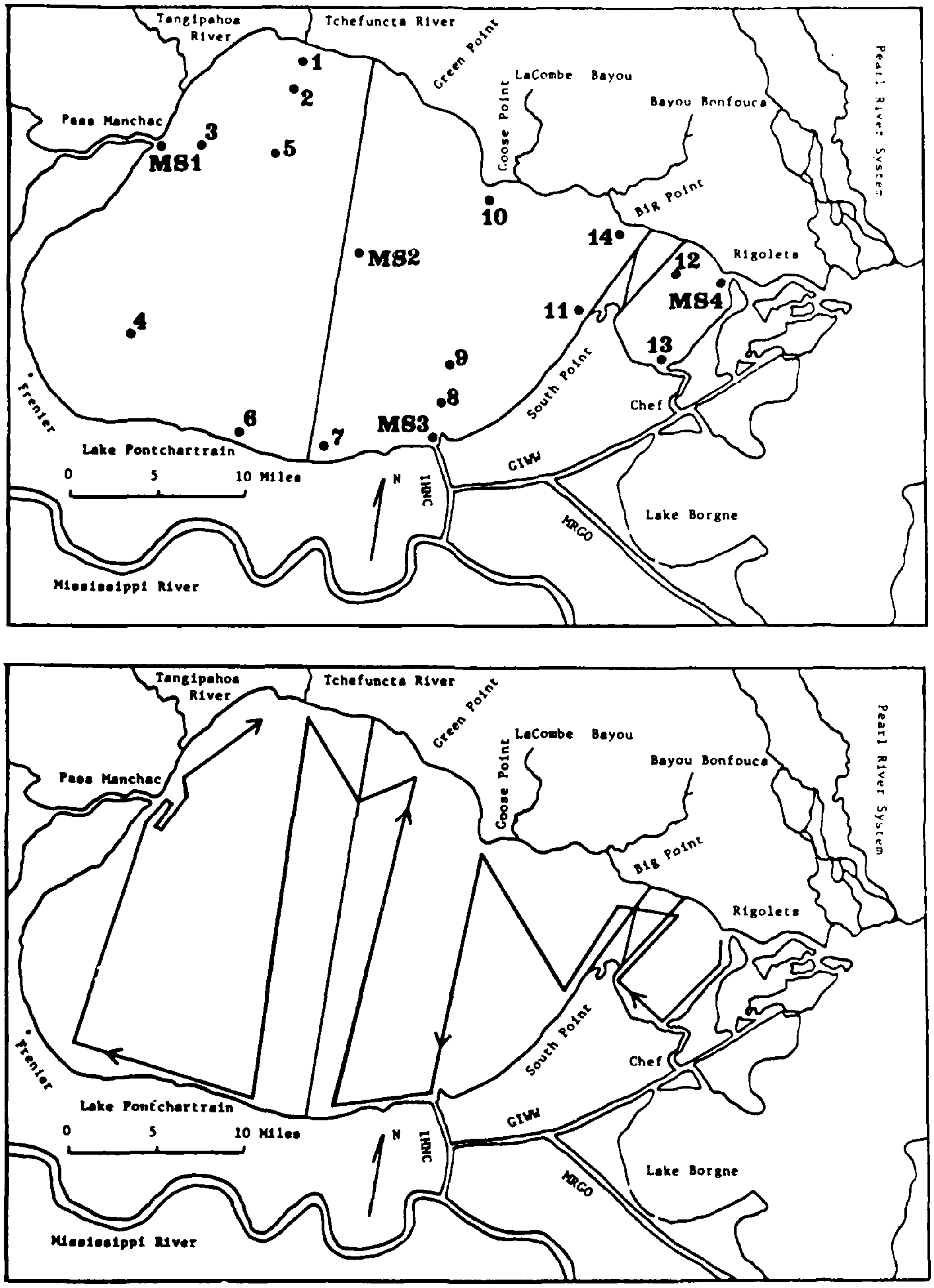


Figure 2. Maps showing station locations (A) and cruise track (B) for conductivity and temperature mapping. Note that stations consisted of 14 Survey Stations and 4 Master Stations in Lake Pontchartrain, LA, 1978-1979.

Table 1. Summary of Cruises Made in Lake Pontchartrain, LA, During 1978-1979

Cruise Number	Date	Comments
01	3/15-17/78	Survey - mapping cruise
02	4/25-28/78	Survey - mapping cruise
03	5/19/78	Survey - mapping cruise
04	5/30/78	Causeway Sampling
05	6/5-6/78	The Rigolets - 24 hour
06	6/20-23/78	Manchac, IHNC
07	6/26-27/78	Causeway
08	7/11-12/78	Chef Menteur Pass - 24 hour
09	7/18-20/78	Survey, drogue
10	8/10-11/78	IHNC - 24 hour
11	8/22-24/78	Survey - mapping cruise
12	9/19-21/78	Anchor Stations
13	10/4/78	Bathmetric Profiles
14	10/5-6/78	IHNC - 24 hour
15	10/9-12/78	Survey - mapping cruise
16	10/26/78	Moored Meters
17	10/30-11/3/78	Experimental
18	11/9/78	Electrode Installation
19	12/4-5/78	The Rigolets - 24 hour
20	12/7-8/78	IHNC - 24 hour
21	12/12-13/78	Survey - mapping cruise
22	1/10/79	Dye Study - Frenier
23	4/3-4/79	Survey - mapping cruise
24	4/26/79	Bonnet Carre Floodway Study
25	5/9/79	Bonnet Carre Floodway Study
26	5/15/79	Bonnet Carre Floodway Study

A vertical profile was made at each station during a cruise. The profiling procedure involved measuring current speed and direction, conductivity, and temperature at one or two meter intervals (depending upon location) from surface to bottom. When the ship was anchored at one spot for an entire day, profiles were made every hour when feasible. The instruments used were an ENDECO type 110 current meter with temperature and depth and a Hydrolab type 8000 CTD (conductivity, temperature, depth) meter.

During the survey cruises, a flow-thru system was used to map surface conductivity and temperature. Water was pumped through a cylinder housing the conductivity and temperature probes. Data were recorded continuously while the ship was underway by use of a chart recorder. The data were later digitized by hand and were used to construct the surface temperature and conductivity maps included in this report. The flow-thru system had a response time of about 30 seconds. Hence, by the time a value from a given location was recorded, the ship had moved about 50 meters.

Navigation was accomplished primarily through the use of RADAR and compass bearings. LORAN-C was used whenever possible. I estimate the error in station location to be a circle with a radius of about 1.2 kilometers.

The manufacturers' specifications with regards to the precision of the current meter are:

Speed		
accuracy	±3%	
threshold	2.57	cm/sec
Direction		
accuracy	±3%	
threshold	2.57	cm/sec

Temperature		
	accuracy	±5°C
Depth		
	accuracy	±2%

The manufacturer's specifications regarding the conductivity, temperature, and depth meter (CTD) are:

Conductivity		
	accuracy	±2.5% ±1.5% with standard solution calibration
	response time	2 seconds
	range	0-20 mmhos/cm
Temperature		
	accuracy	±.2°C
	response time	10 seconds
	range	-5-45°C
Depth		
	accuracy	±.3m
	range	0-20m

The conductivity probe was standardized periodically; hence, our accuracy was the 1.5% figure. All conductivities are internally referenced to 25°C by the CTD meter. A conversion of conductivity to salinity is given in Appendix Table 4. Because the temperature accuracy of the CTD is better than that of the temperature sensor on the current meter, all temperatures used were those measured by the CTD.

DATA PRESENTATION

I. Currents

Appendix 1 Figures A1-1 to A1-5 show a series of current profiles measured at various locations and times within the lake. In general the profiles show a decrease in current speeds from 10-20 cm/sec at the surface to values as low as 5 cm/sec at near bottom (about 1 m off at bottom). The direction remains fairly constant from top to bottom, with

the maximum variation being approximately 60 degrees (the average being less than 20 degrees). This type of profile indicates that Lake Pontchartrain is a vertically well-mixed system.

The current data are summarized in Figure 3, which shows histograms of current speeds for the four seasons of the year. (Winter = December, January, and February; spring = March, April, and May; summer = June, July, and August; fall = September, October, and November.) The average is computed for each season along with the 95% confidence interval of the mean. Figure 4 shows a similar plot for current speed data collected by the COE (1962). These data indicate that average current speeds within the lake are in the range of 12-14 cm/sec.

II. Conductivity, Temperature

Appendix 2 Figures A2-1 to A2-10 show a series of profiles of conductivity and temperature at various locations and times within the lake. Figures 5-7 show sections of the lake along the Lake Pontchartrain Causeway with contoured values of conductivity and temperature. In general, the profiles show a slight increase in conductivity (∿1 to 2 mmhos/cm) from surface to bottom at stations located away from the tidal passes. At stations located near the tidal passes or rivers, this increase is greater, being about 6-9 mmhos/cm (Fig. A2-1, A2-2, A2-4, and A2-6). The temperature profiles show a general decrease of about 1 to 2° C from surface to bottom. This temperature difference is more pronounced in the spring and summer than in the fall (see Fig. A2-9).

Figure 8 shows a time series plot of both temperature and conductivity within the lake from data collected during this study. There is a significant difference in the average conductivity of each side, but

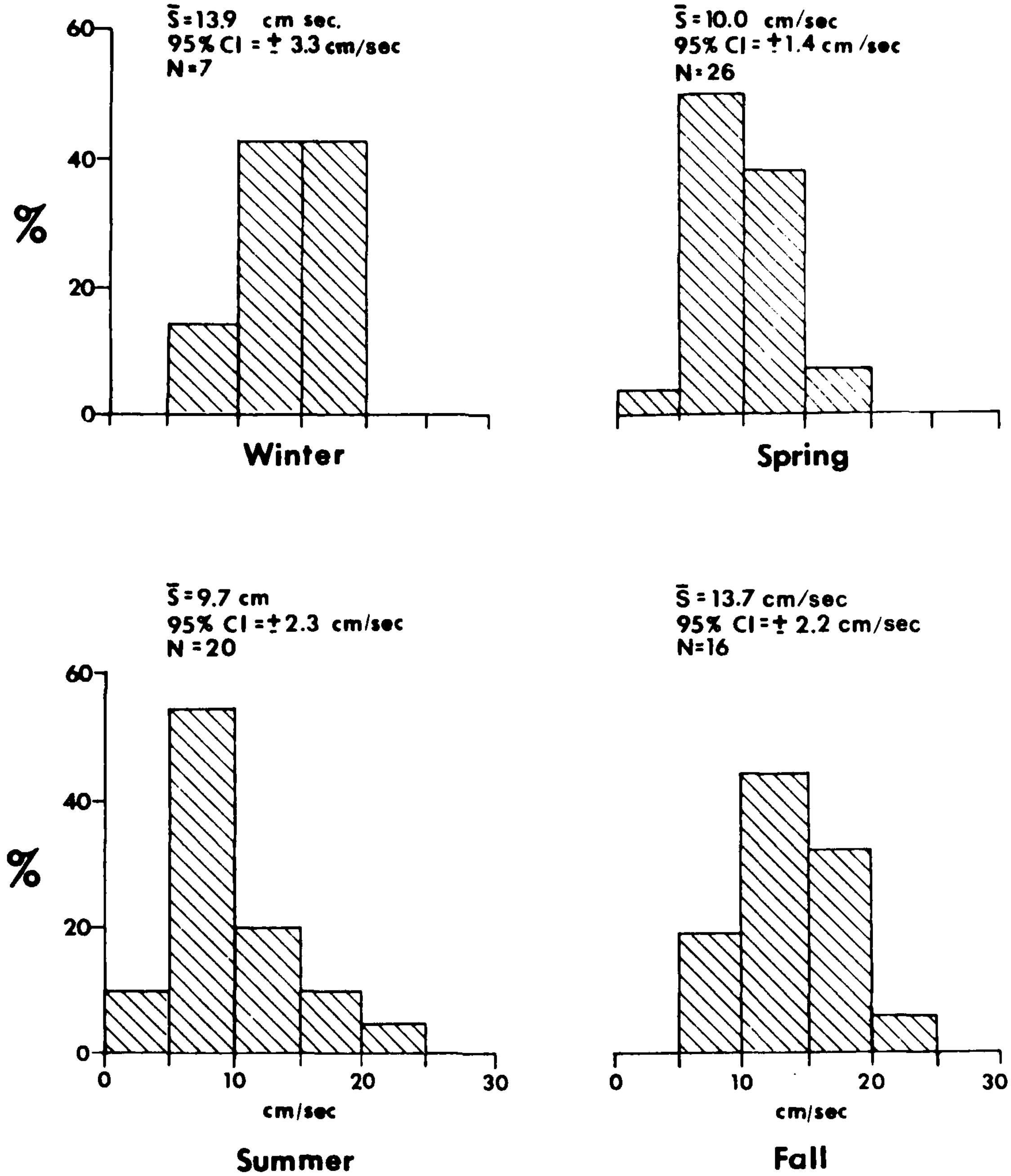


Figure 3. Histograms showing distribution of average lake current speed in Lake Pontchartrain, LA for each season of the sampling year (1978-1979). The mean (S̄), the 95% confidence interval (CI) of this mean, and the number of samples (N) are indicated at the top of each histogram. Winter = Dec., Jan., and Feb.; spring = March, April, and May; summer = June, July, August; fall = Sept., Oct., and Nov.

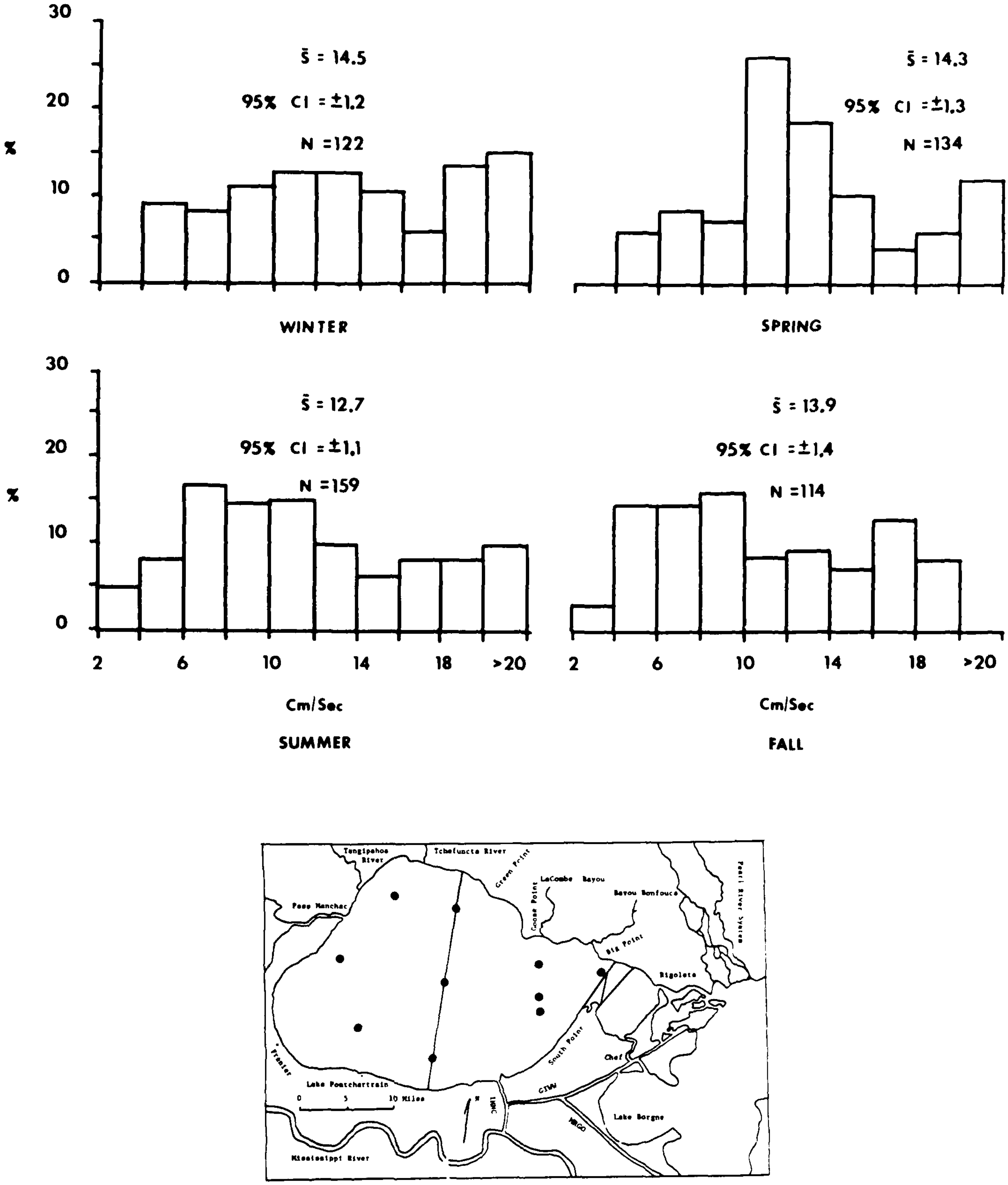


Figure 4. Histograms showing distribution of average lake current speed for each season, from U.S. Army Corps of Engineers data (1962). The mean ($\bar{S}$), the 95% confidence interval (CI) of this mean, and the number of samples (N) are indicated at the top of each histogram. The map at the bottom shows the sample locations in Lake Pontchartrain, LA, 1978-1979.

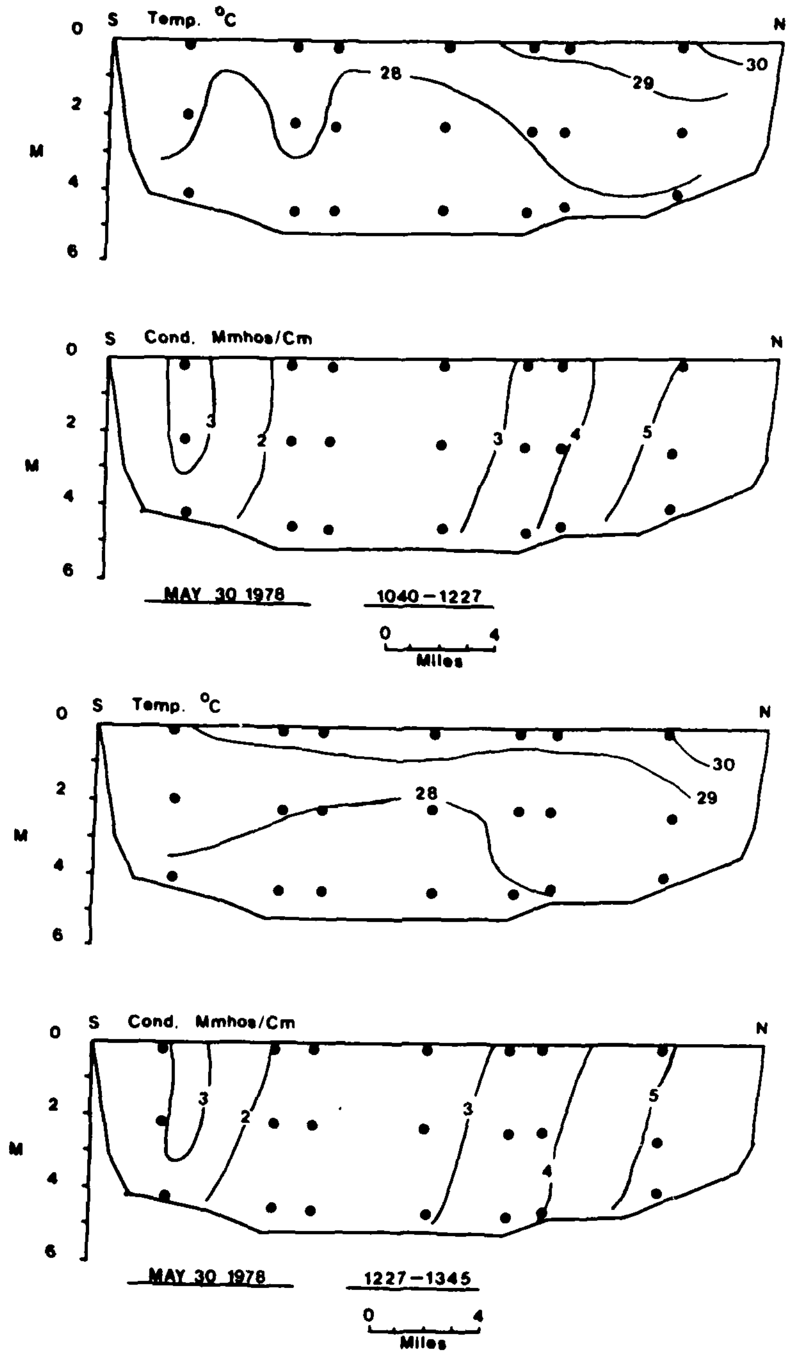


Figure 5. Cross section of Lake Pontchartrain along the Lake Pontchartrain Causeway with contoured values of temperature (°C) and conductivity (mmhos/cm). The dates and times of the sections are indicated in the lower left corner.

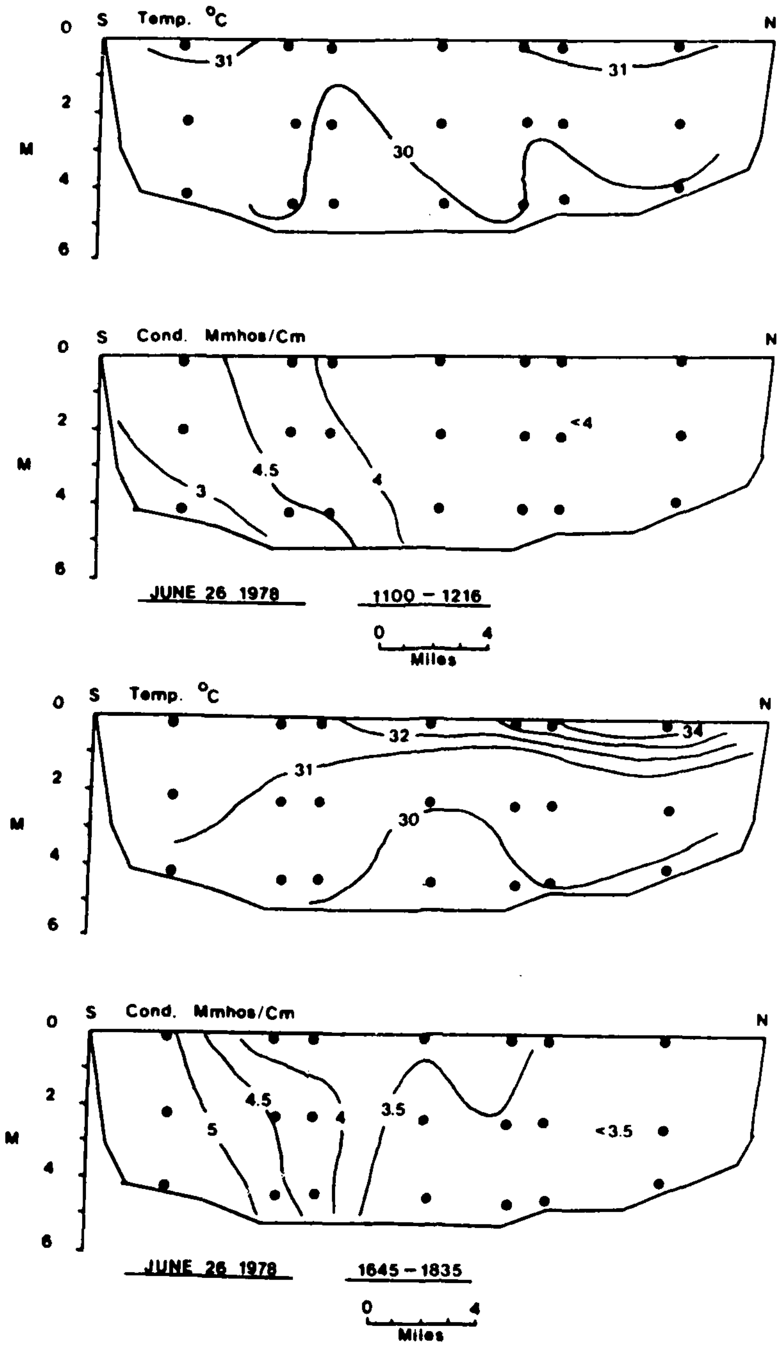


Figure 6. Cross section of Lake Pontchartrain along the Lake Lake Pontchartrain Causeway with contoured values of temperature (°C) and conductivity (mmhos/cm). The dates and times of the sections are indicated in the lower left corner.

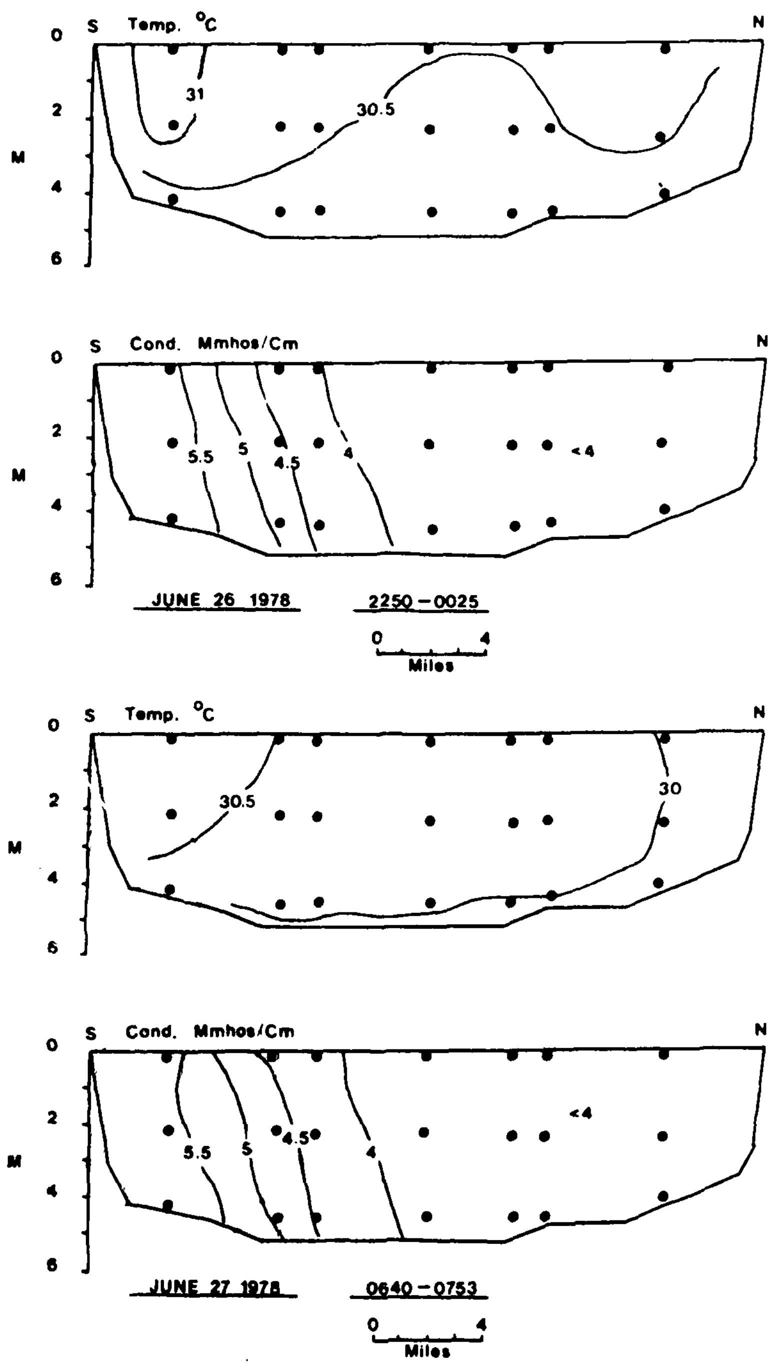
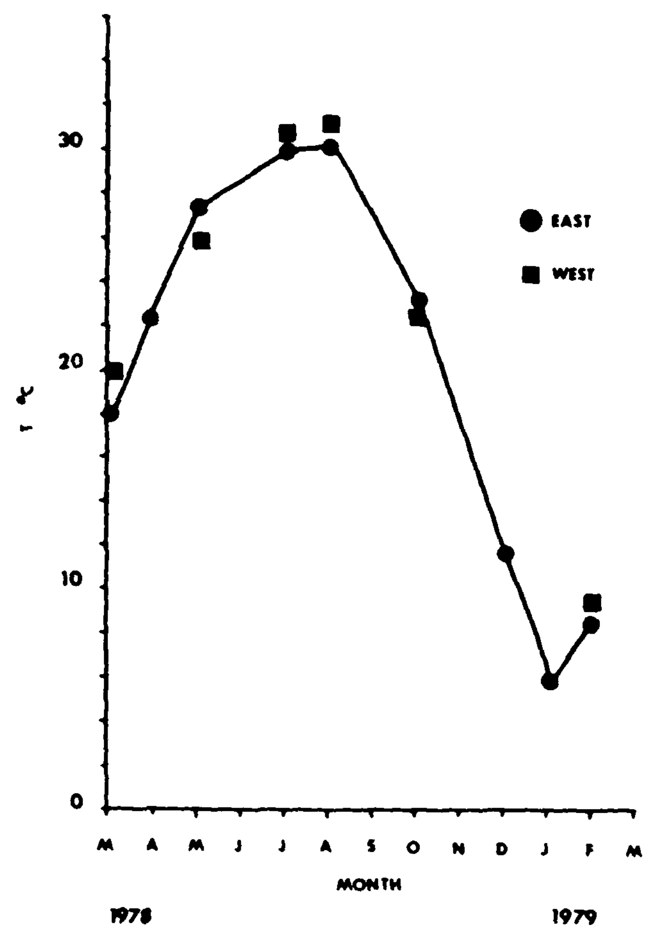
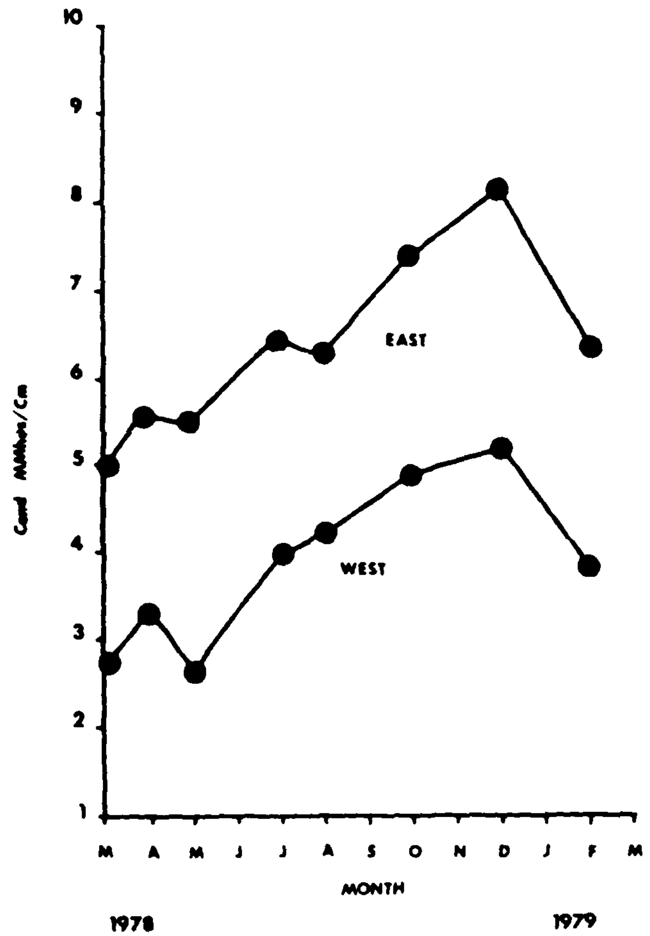


Figure 7. Cross section of Lake Pontchartrain along the Lake Pontchartrain Causeway with contoured values of temperature (°C) and conductivity (mmhos/cm). The dates and times of the section are indicated in the lower left corner.



Temperature



Conductivity

Figure 8. Time series plot of temperature (^{o}C) and conductivity (mmhos/cm) in Lake Pontchartrain for 1978-1979. "East" is the area east of the Lake Pontchartrain Causeway and "West" is the area west of the Causeway.

there is little temperature difference from east to west. "East" is the area east of the Lake Pontchartrain Causeway and "west" is the area west of the Causeway.

The surface conductivity and temperature maps are presented in Appendix 3.

III. Tides

Tidal heights were monitored during 1978-1979 by the Waterways Experiment Station (WES) at several locations within the lake system. These data are presented in a report by Outlaw (1979). Some of these data are presented here to give a general picture of the tidal signal within the lake. Figure 9 shows the average tidal range within the lake, and Figure 10 is an example of the tidal signal at four locations, (from COE tidal gages in Lake Pontchartrain). The diurnal period is prevalent, although interference from other events (winds) is also evident. Figure 11 presents the phase lag (in hrs) relative to a station off the mouth of the Pearl River (B-2 on Figure 11) of the O1 and K1 tidal constituents at several points within Lake Pontchartrain. The O1 and K1 constituents have been shown to be the dominant diurnal constituents in Lake Pontchartrain (Outlaw 1979). These data indicate that there is very little phase lag between the three tidal passes. It can also be seen that there is essentially no phase lag between the stations along the Lake Pontchartrain Causeway and the station near Pass Manchac. This pattern indicates that the tide in the lake is a forced oscillation, with the water level over the entire lake rising and falling as a unit.

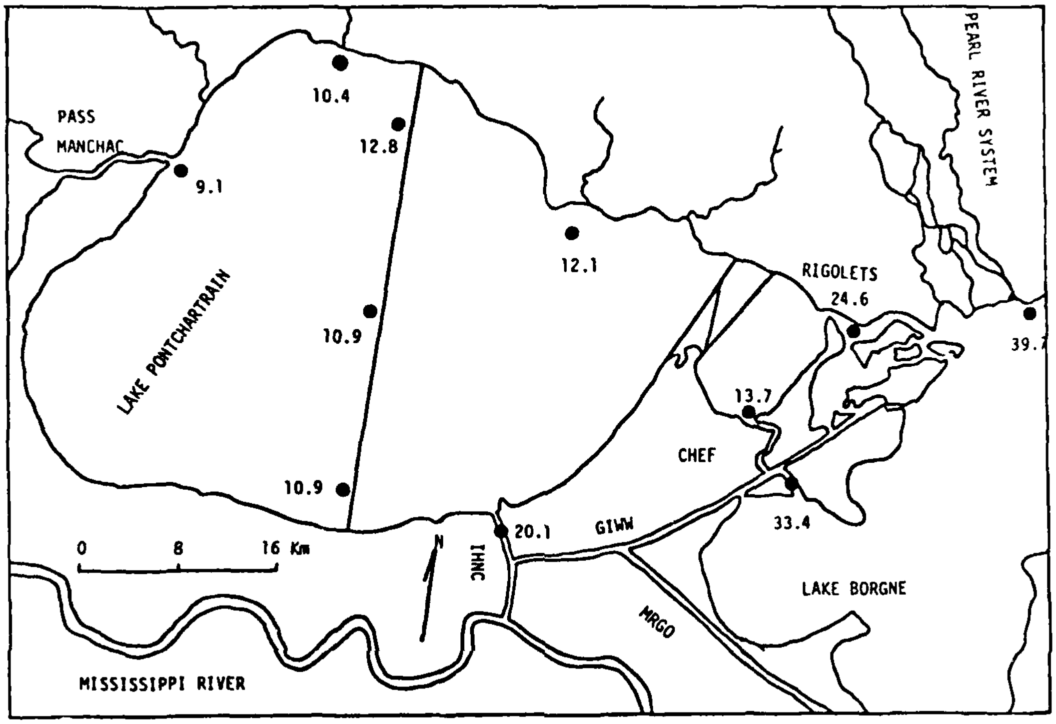


Figure 9. Map showing tidal range (in cm) at various locations in Lake Pontchartrain (based on data collected by WES [Outlaw 1979]).

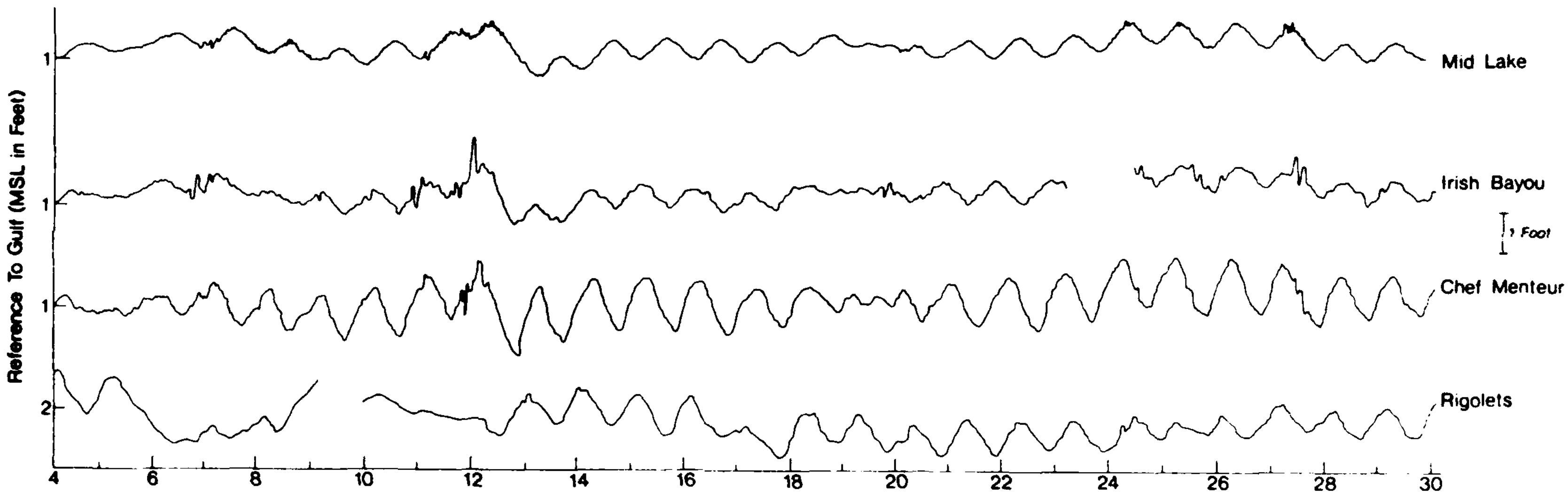


Figure 10. Examples of tidal gage records at four locations in the Lake Pontchartrain system for the month of April 1963. The locations are given to the right of each plot.

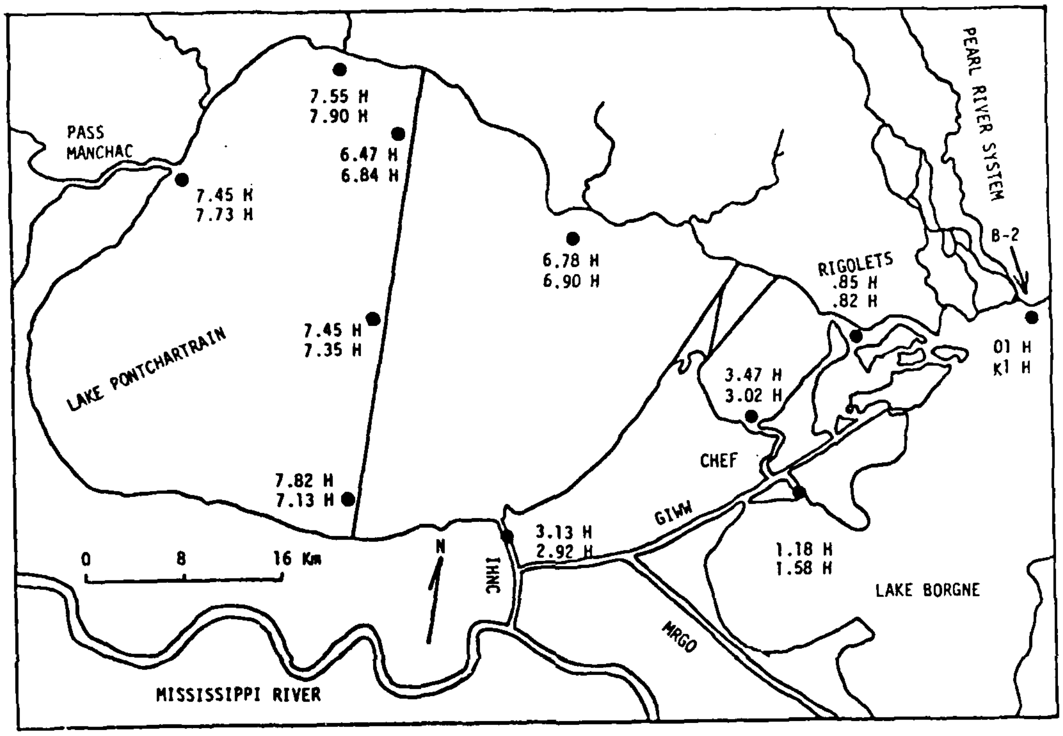


Figure 11. Phase lag of the O1 (top) and K1 (bottom) tidal constituents (in hours) relative to station B-2, at the mouth of the Pearl River (based on data collected by WES [Outlaw 1979]).

Figure 12 shows time series plots of the percent of winds coming from the east (top) and the mean monthly lake level (bottom) for the sampling year. The wind data are based on the daily, resultant wind speeds at New Orleans International Airport (from National Oceanic Atmospheric Administration [NOAA] records). The daily data for each month were grouped into 30° intervals, and the percent of values in each interval was computed. From these data, the percent of wind from the east (60-150°) was computed.

Mean monthly lake level was computed by averaging the 8 A.M. readings (from COE tide records) for five gages in the lake for each month. The gages used were: Irish Bayou, Mandeville, Mid-lake, West End, and Frenier. These data show two peaks in mean lake level, one in the spring, and the other in the fall, which correspond to similar peaks in the east wind. However, the Gulf of Mexico itself also has a spring and fall peak in mean level (Marmer 1954).

Thus, the level of Lake Pontchartrain is controlled by a combination of the Gulf tides and the forcing of easterly winds (driving water into the lake). The data presented here are not sufficient to separate out each of these two components. To do so, synoptic measurements of wind and water level would be needed at intervals of several hours as opposed to once a day. However, it is likely that the wind effect is quite pronounced in this shallow system with a low tidal range (Marmer 1954). On the basis of these data, it can be concluded that the mean monthly level is primarily controlled by the forcing of the wind. It is probable that this effect occurs over a wider area than Lake Pontchartrain and includes Lake Borgne and the Mississippi, Chandeleur, and Breton Sounds.

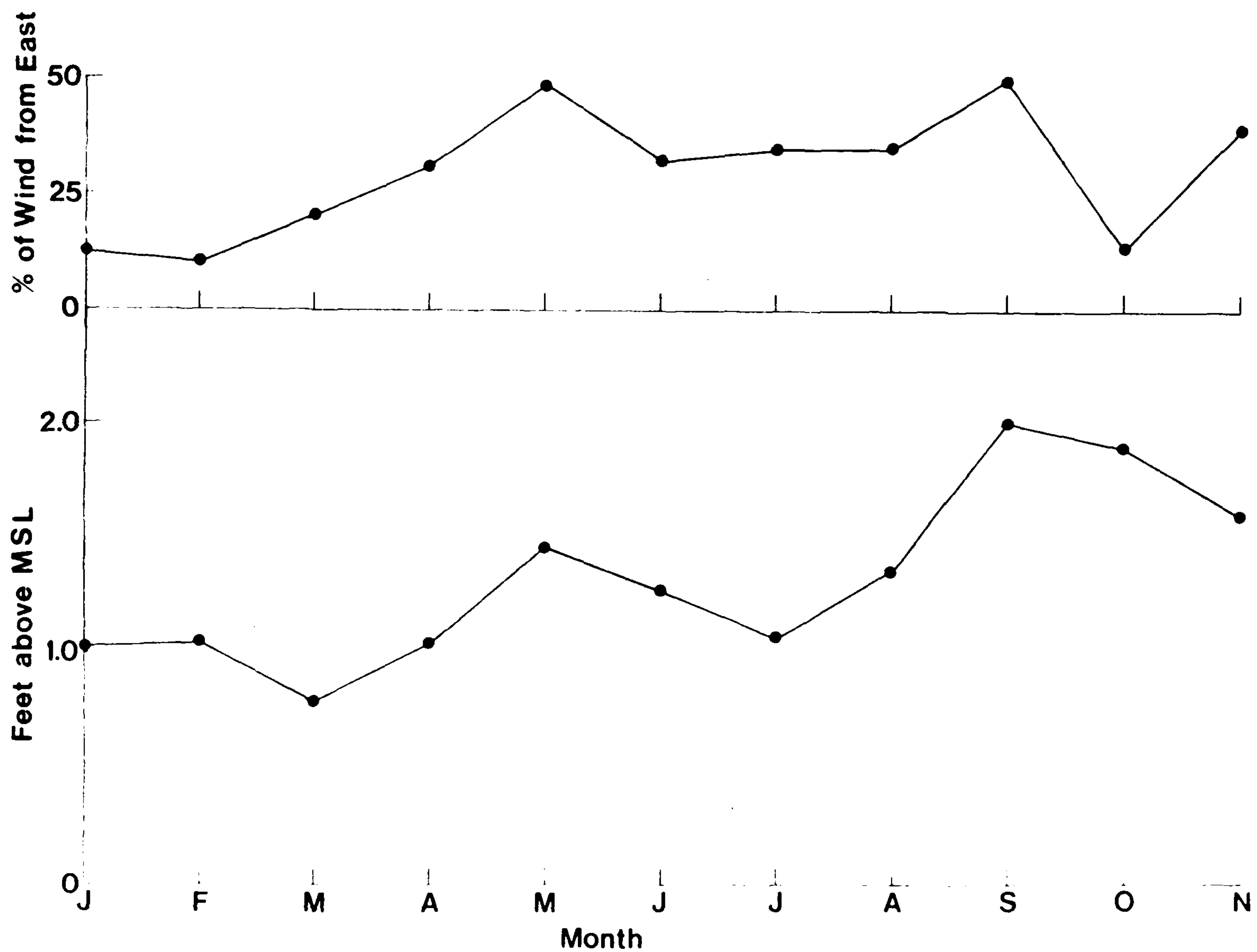


Figure 12. Plot showing the percent of time winds are from the east (top) and the mean monthly level of Lake Pontchartrain for 1978-1979. See text for explanation.

IV. Wind and Waves

During the late 1950's and early 1960's, the COE collected simultaneous wind and wave data at various locations in the lake system (North Shore, South Shore, and Frenier). A time series plot of wind and wave data collected on May 30, 1959 at the North Shore station is presented in Figure 13. There is a direct relationship between wind speed and wave height that will be discussed in detail later. These data also show that there is very little response time between an increase in wind speed and the corresponding increase in wave height.

DISCUSSION

I. Climatic Characterization of the Sampling Year

A. Introduction

If the ecological data are to be compared to other data collected in the lake system, it is desirable to characterize the lake in terms of some of the basic environmental paramters. Various parameters measured during this study were compared to historical data. These parameters include: air temperature, rainfall, streamflow, and lake salinity.

B. Data

Figure 14 shows a plot of deviations from the mean for some of the parameters mentioned on a monthly basis from December 1977 to December 1978.

The air temperature deviation (top graph) and rainfall deviation (second graph) are based upon (NOAA) records from east central Louisiana. The mean used for each month was the standard 30 year mean (1948-1978) used routinely by NOAA.

The streamflow deviation curves (2nd and 3rd from top) are based upon U.S. Geological Survey (USGS) streamflow records. The long-term

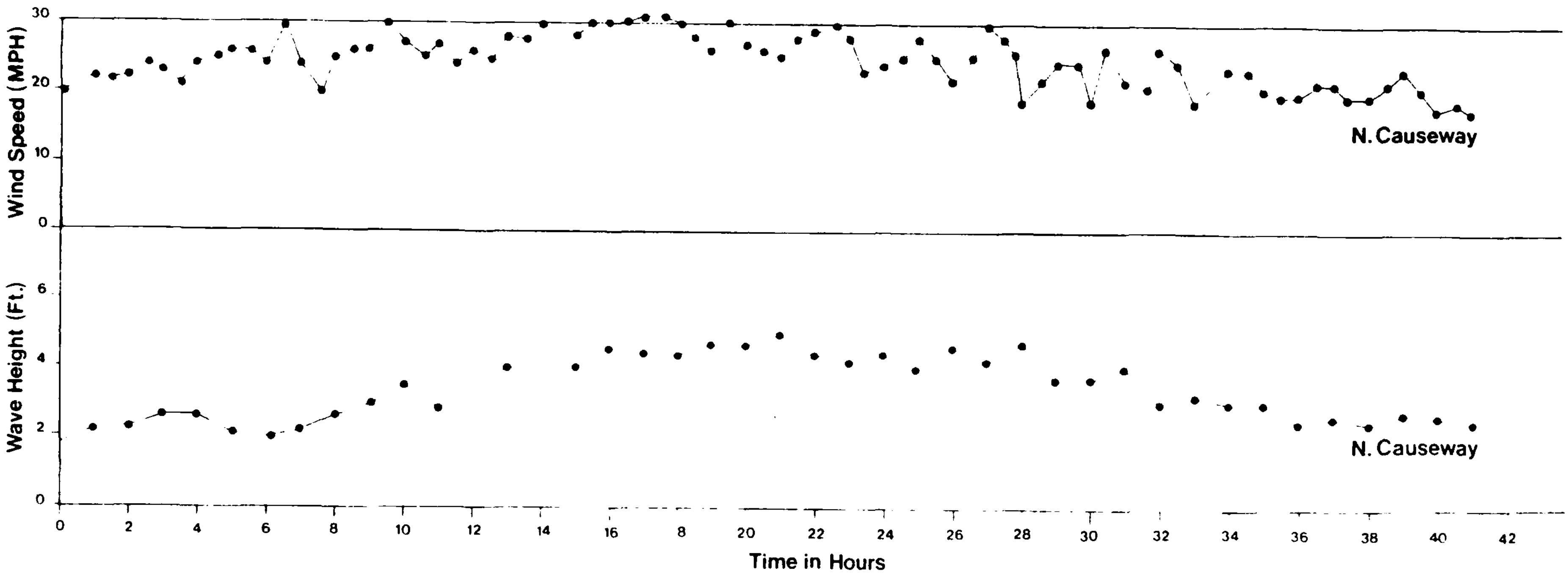


Figure 13. Time series of wind speed in miles per hour (top) and wave height in feet (bottom) collected in Lake Pontchartrain by the Corps of Engineers (1962).

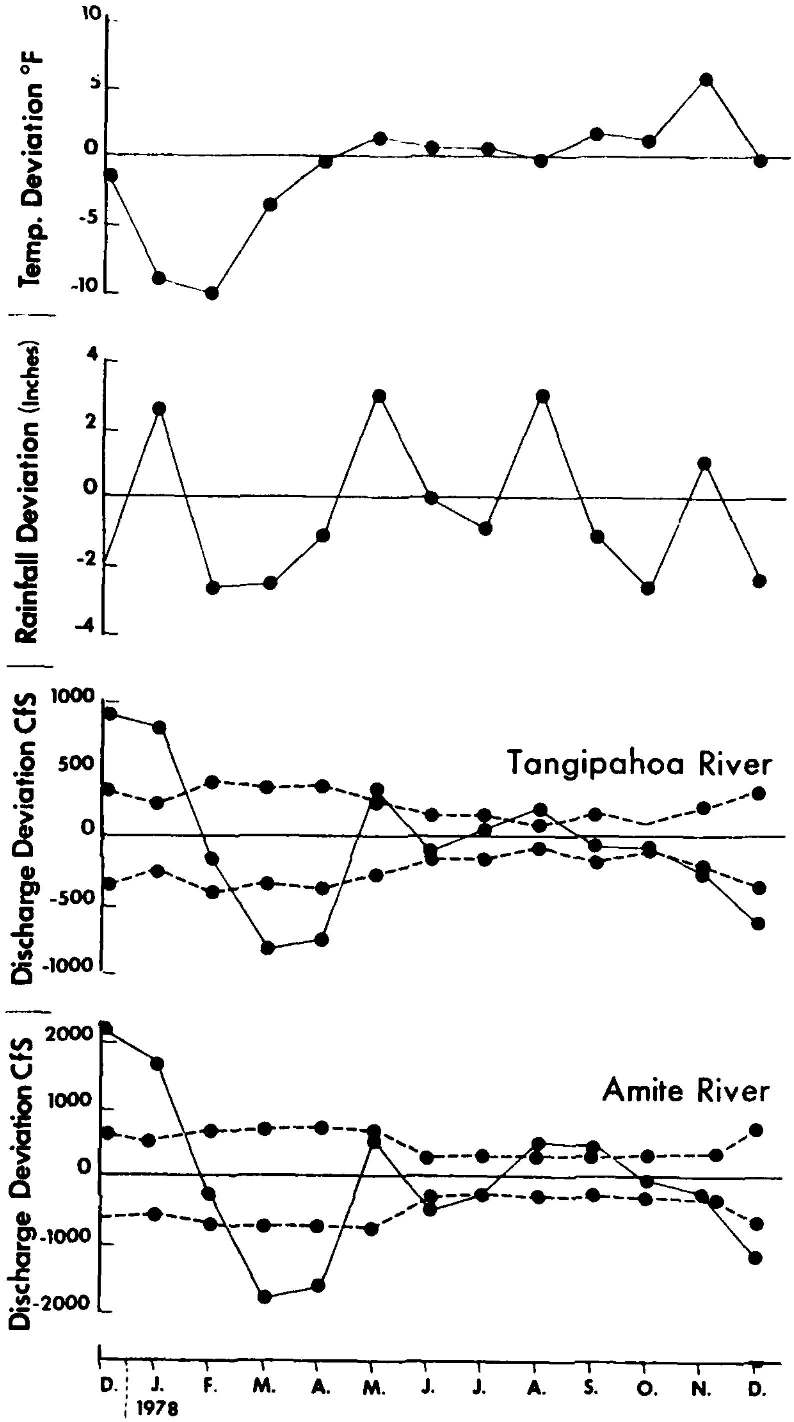


Figure 14. Plots showing the deviations from average of (from top to bottom): air temperature (°F), rainfall data from East Central Louisiana (inches), Tangipahoa River discharge (cfs), Amite River discharge (cfs), for December 1977-1978. See text for explanation.

monthly mean for a given month was calculated by taking the average of the USGS monthly means for that month from 1939 to 1978. The dashed lines on the curves represent the 95% confidence level of the long-term monthly means. The Tangipahoa and Amite Rivers together account for about 75% of the freshwater input into the lake (see water budget calculations, Chapter 5).

Figure 15 shows a plot of the 10-year mean monthly salinity at Little Woods (COE 1962) and the salinity measured at South Point during this study. It has been assumed that these stations are valid indications of the general salinity trends in the lake.

C. Discussion of Climatic Characterization

Assuming that the data in Figures 14 and 15 are fairly accurate representations of the basic physical parameters affecting the lake, it is possible to classify our sampling year by season as shown in Figure 16. The horizontal bar in the figure is an attempt to account for the variation that occurs during a season. For example, if all values of parameter were normal for a given season, then the horizontal bar would be centered on normal. However, if a majority of the values were low but one high value made the average normal, then the bar would be shifted towards the low end but closer to normal than low.

Temperature was in general lower in the winter (December, January, and February), approximately normal in spring (March, April, and May) and summer (June, July, and August), and higher in the fall (September, October, and November). Rainfall was, in general, on the lower side of normal. Streamflow was normal for the summer season, higher than normal in the winter, and lower than normal in the spring and fall. Lake salinity followed the general pattern of low values in the spring and a peak in the fall.

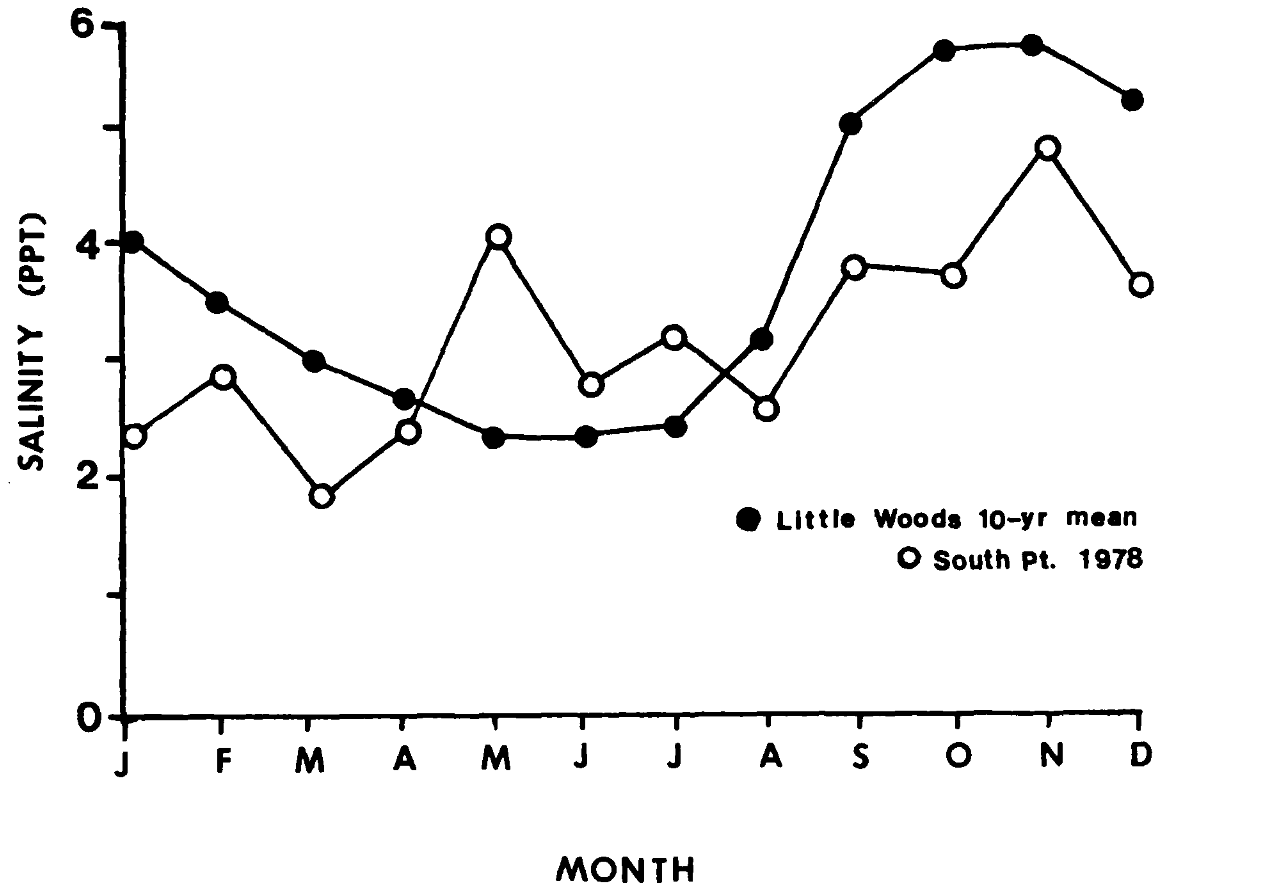


Figure 15. Plot of 10-year mean monthly salinity at Little Woods (from COE records) and salinity at South Point measured during this study.

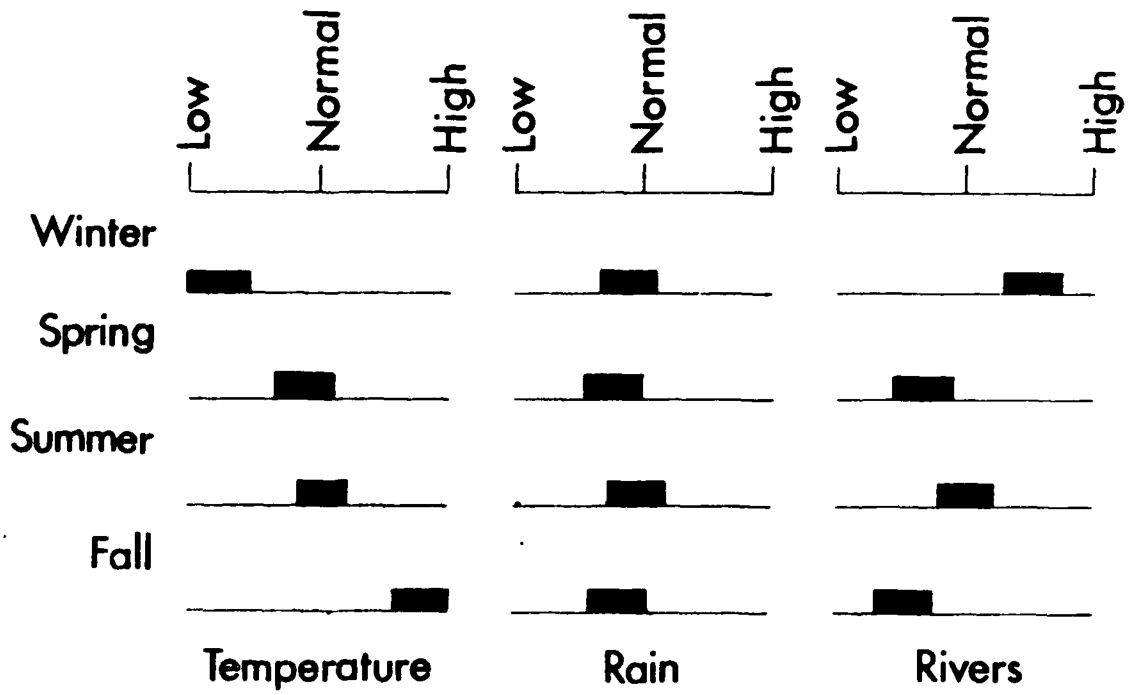


Figure 16. Classification of the sampling year (1978) by season, based on temperature, rainfall, and river discharge in Lake Pontchartrain. The location of the horizontal bar indicates whether the seasonal average of a given parameter was lower, equal to (normal), or higher than the long-term mean for that season. Winter=Dec., Jan., and Feb.; spring=March, April, and May; summer=June, July, and Aug.; fall=Sept., Oct., and Nov.

II. General Circulation

The current data collected were not adequate to enable the construction of vector plots that would show the general circulation. Because it took 12 hours to sample the lake, it is impossible to separate the temporal and spatial changes. However, the current data were useful in determining values for the mean current speeds within the lake (Fig. 3). A summary of the large-scale drift patterns is presented here; the reader is referred to Gael, Chapter 3, for details.

Both Gael (Chapter 3) and Stone et al. (1972) have demonstrated that Lake Pontchartrain is primarily a wind- dominated system. In general, the edges of the lake are characterized by longshore boundary currents; the direction of these currents is apparently determined by the wind direction. For example, with a northeast wind, a counterclockwise gyre develops in the southwest portion of the lake that initiates an eastward current along the south shore. The center of the lake is dominated by large-scale gyres whose orientation and circulation pattern are dependent on the wind direction.

III. Temperature and Conductivity Patterns

The temperature and conductivity profiles both show some degree of stratification within the lake system. In most cases, the conductivity stratification is fairly slight and would not be significant as far as the general biology of the lake is concerned. This is shown by the primary production data, which show (in general) no vertical stratification (Dow and Turner, Chapter 7). However, it is possible that density differences associated with conductivity (salinity) and temperature differences could be large enough to induce a secondary density-driven

flow. In order to evaluate this possible second order effect, long-term synoptic measurements of salinity and temperature (density) at several locations would be needed. Such data are presently unavailable.

The temperature profiles show a temperature gradient usually in the upper meter of water. This is noticeable on the Causeway sections (Fig. 5-7). This effect is most likely due to diurnal heating, because the stratification is less pronnounced at night (Fig. 6-7) and during the fall months (see Fig. A2-9).

The most evident feature of the conductivity and temperature maps (Appendix 3) is the horizontal conductivity stratification. In general, the lake has an eastern half dominated by the tidal exchange and a western half dominated by streamflow. The conductivity maps show "tongues" of saltier water that appear to spread across the lake, dividing it along a northeast-southwest line (from Green Point to Walker Canal). (See Fig. A3-4, A3-6, A3-8, A3-10, A3-12, and A3-14.)

Since this division appears to be a year-round feature (Fig. A3-4, A3-6, A3-8, A3-10, A3-12, and A3-14), one would expect the ecology of the lake (particularly the benthos) to be adjusted to it. This appears to be the case, because the benthic data collected during this study, particularly the distribution of Mulinia pontchartrainensis, Macoma mitchelli, and the chironomids, show an east-west difference. Thus, a change in this stratification pattern could affect the distribution of bottom-dwelling organisms in the lake.

The temperature map shows a general structure in which the lake is usually slightly warmer in the center. This pattern could result from the influx of colder river runoff along the lake edges that is confined to the edges by the longshore boundary currents discussed in the circulation

section. In addition, the large-scale gyres mentioned would serve to trap water in the lake center that would then be heated by solar radiation.

In summary, based upon the data collected, one could classify Lake Pontchartrain as a weakly vertically stratified but strongly horizontally stratified system.

IV. Bottom Resuspension

A. Introduction

The fine-grained sediments found in large lakes such as Lake Pontchartrain may contain large amounts of nutrients, trace metals, and other man-made contaminants (Sheng and Lick 1979). The resuspension of these sediments with their associated materials may occur by tidal currents, wind-induced waves, or man's activities (dredging).

This section discusses the physical aspects of sediment resuspension in the lake to determine under what natural conditions sediments may be resuspended in the lake.

B. Physical Considerations

In considering the problem of sediment resuspension, it is first necessary to define the level of sediment motion with which we intend to deal. The criterion for incipient sediment motion could be any of the following (Garde and Raju 1977):

(a) a single particle moving;

(b) a few particles moving;

(c) general motion of the bed;

(d) limiting condition when the rate of sediment transport tends to zero.

In this discussion, we will use condition (c) as the criterion for incipient sediment movement, since this is the most likely condition under which the ecological effects would become important. Sediment resuspension can be defined as "the point when the sediment particles leave the bottom and are carried into suspension by turbulent eddies within the flow."

The initial motion of bottom sediments is usually related to the bottom shear stress (τ_C^B). This shear stress arises because there is friction when the water flows over the bottom. The stress is given by the general relationship (Sheng and Lick 1979):

$$\tau_C = \rho \, f \, U_B^2 \tag{1}$$

Where:

ρ = density of water

f = friction coefficient (dependent upon bottom material) $\sim .004$

U_B = local bottom velocity

This stress can result from either tidal currents or wind waves. In the case of tidal currents, the stress is simply given by (Sheng and Lick 1979):

$$\tau_C^B = \rho \, f_C \, U_B^2 \tag{2}$$

Where:

τ_C^B = bottom stress due to currents

ρ = density of water

f_C = friction term $\sim .004$

U_B = bottom current

The bottom stress due to waves at any instant in time (t) is given by (Sheng and Lick 1979):

$$\tau_W^B = \rho \, f_W \, U_M^2 \cos \frac{2\Pi\tau}{TS} \cos \frac{2\Pi\tau}{TS} \tag{3}$$

Where:

τ_W^B = bottom stress due to waves

U_M = bottom current due to waves

T_S = wave period

The bottom current due to the waves is calculated with the aid of the following relationships (Sheng and Lick 1979):

$$U_M = \frac{\Pi H_S}{T_S \text{ Sinh } (\frac{2\Pi d}{L_d})} \tag{4}$$

Where:

H_S = significant wave height

T_S = significant wave period

d = local depth

L_d = wavelength for depth d

The wavelength L_d is defined by:

$$L_d = L \tanh \frac{2\Pi d}{L_d} \tag{5}$$

$$L = \frac{g\ T_S^2}{2\Pi} \tag{6}$$

For a further simplification, Sheng and Lick (1979) have considered the average wave shear stress over a wave period T_S.

Computing the average, one arrives at the following formula for the average wave shear stress:

$$\tau_W^B = \frac{\rho\ f_W\ U_M^2}{2} \tag{7}$$

Using these relationships, it is possible to calculate the bottom stresses from a given tidal current or a given wave. However, the stresses needed to move or resuspend the sediments in the lake must be known before it can be determined whether the sediments will be affected.

These so-called "critical stresses" depend upon the nature of the sediment itself and are usually determined experimentally.

Through the use of literature estimates for critical stresses on sediments similar to those in Lake Pontchartrain as well as wave and current data from the lake, an estimate of resuspension can be made. These results are presented in the next section.

C. Application to Lake Pontchartrain

During the late 1950's and early 1960's, the COE collected simultaneous wind and wave data in Lake Pontchartrain (see Fig. 13). Figure 17 shows a plot constructed from these data of wave period as a function of wave height. Using this plot along with equations 4, 5, 6, 7, it was possible to determine the bottom stress as a function of a given wave height. These results are presented in Table 2.

The majority of the sediment in the center of the lake fall in the general classification of silty-clay (based upon data collected by the benthos part of this study [Bahr et al., Chapter 11]). From literature estimates of critical stresses (Table 3), it appears that sediments in the Lake Pontchartrain system will begin moving at a stress of about 1.0-2.0 dynes/cm^2, with total resuspension occurring at approximately 10 dynes/cm^2. These stresses would correspond to wave heights of approximately 0.75 m and 1.3 m, respectively. These wave heights can be related to wind speed through the use of Figure 18, which gives wave height as a function of wind speed, based upon data collected in the lake system by the COE. The data follow quite closely the relationship given by the wave hindcasting tables found in Bretshneider (1966). From Figure 18 it was determined that sediment movement in the lake begins at a wind speed of about 15 mph (6 m/sec) and that complete resuspension occurs at a wind speed of about 38 mph (17m/sec).

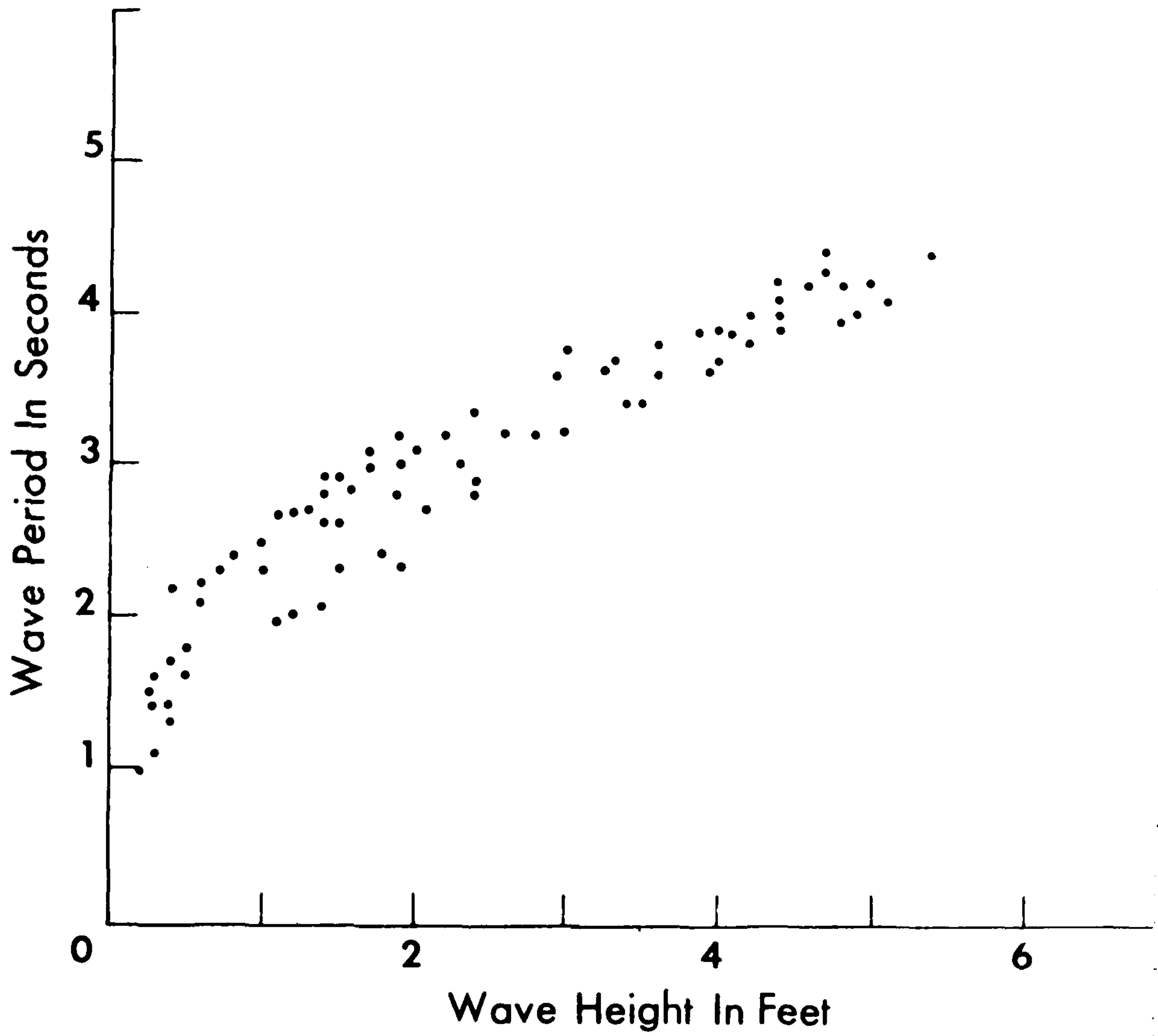


Figure 17. Plot showing wave period (in seconds) as a function of wave height (in feet) for data collected in Lake Pontchartrain (U.S. Army Corps of Engineers 1962).

Table 2. Calculation of Bottom Stress (τ_W^B) in Lake Pontchartrain, LA

$H_{(M)}$[1]	$T_{(sec)}$[2]	$L_{(M)}$[3]	$Ld_{(M)}$[4]	$U_{M(cm/sec)}$	$\tau_W^B (dynes/cm^2)$[6]
.27	2.0	6.2	6.2	1.5	.01
.73	3.0	14.0	13.4	24.0	1.15
.85	3.2	15.9	14.8	31.8	2.02
1.10	3.6	20.2	17.8	50.1	5.02
1.40	4.0	25.0	20.8	72.1	10.40
1.61	4.2	27.5	22.2	87.3	15.20
1.74	4.5	31.6	24.4	100.0	20.00

[1]Values for H were chosen.

[2]From Figure 16 after choosing H.

[3]From Equation (6).

[4]From Equation (5).

[5]From Equation (4).

[6]From Equation (7).

Table 3. Critical Shear Stresses for Materials Similar in Size to those Found in Lake Pontchartrain, LA

τ in dynes/cm^2 Movement	Resuspension	Material	Author
3.4	12.6	Clay & Silt	Bretschneider, 1966
2.0	12.0	Clays	McDowell and O'Connor, 1977
1.8-2.0	----	Quartz Sand .2-.4 mm	Garde and Ranga Raju, 1977
2.0	10.0	Clays & Silts	Sheng and Lick, 1979
1.0-2.9*	----	Medium Sand to Coarse Silts	Rhoads et al., 1978
----	6.0*	Medium Sand .18 mm	Lavelle et al., 1978
1.0	5.3	Carbonates ∿.2 mm	Wimbush et al., 1979

*Inferred by present author from bottom current data.

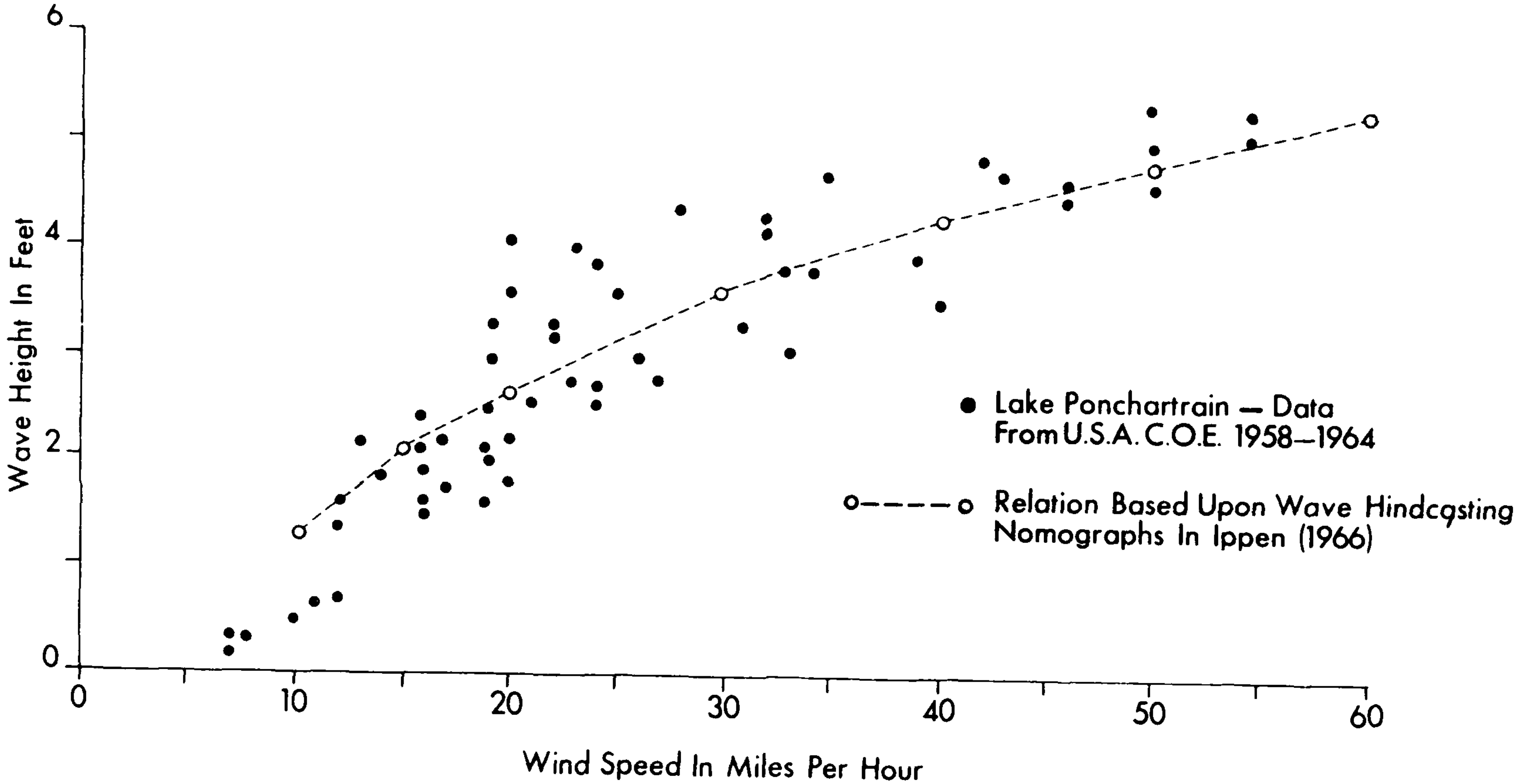


Figure 18. Plot showing wave height in feet as a function of wind speed in miles per hour for Lake Pontchartrain. The dashed line shows the relationship based upon wave hind-casting methods. See text for explanation.

The average bottom tidal currents within the lake (5-10 cm/sec) will induce a bottom stress less than 0.5 dynes/cm^2 (from equation 2). Thus, in general the average tidal currents in the lake are not capable of moving the sediments. Instead, the motion is accomplished by the action of wind-induced waves. However, once the material has been set in motion, it can then be carried by the tidal currents.

The determination of critical stresses on sediments is still in the beginning stages. Most values are determined by flume studies, and the relation to the environment is somewhat sketchy because factors such as mineralogical content, water content, and percent of organic matter must be taken into account. This has not been done.

In addition, the effects of organisms such as microbial growth, mucus binding, and the development of worm tubes have been ignored. It has been estimated (Rhodes et al. 1978) that these effects may change the critical stresses by up to 80%. Thus, the discussion is only a first attempt to evaluate the sediment resuspension problem in Lake Pontchartrain. However, it does provide a basis for investigating some general trends.

D. Implications

The discussion thus far has shown that the sediments in Lake Pontchartrain are capable of being moved by waves induced by fairly small wind speeds ($\sim$15 mph [$\sim$6m/sec]). The movement of these sediments affect exchanges that influence the productivity of the water column and may act as a food supply for the benthic community (Oviatt et al. 1975). In addition, movement of the bottom layer may also serve to disperse small benthic organisms (J. Sikora, personal comm. 1979). Wind data from the

lake area (see Gael, Chapter 3) indicate that winds of this magnitude (15 mph [6m/sec]) or greater occur about 15% of the time. Thus, we are lead to conclude that the bottom is in motion about 15% of the time due to natural causes.

When winds are such that the material is brought into suspension, its redistribution will then be determined by the current pattern in the lake. Stone et al. (1972) have shown that a westerly flowing current may develop along the south shore. In this case, the interaction of the waves and currents could serve to disperse materials that have entered the lake from New Orleans and have settled on the bottom. Similar situations may also occur around the other edges of the lake.

The center of the lake appears to be dominated by large-scale gyres. These gyres are evidenced in both the drift pattern predictions (Gael, Chapter 3) and in the Stone et al. (1972) data. These gyres will influence the way material resuspended by the wave action will be redistributed. In general, material resuspended in the center portion of the lake will probably be redistributed within the center portion. However, some of the material may be carried by the currents along the edges. The resuspension may also be accompanied by a release of nutrients and/or toxic materials to the overlying water column (Sheng and Lick 1979).

V. Marsh Flooding

A. Introduction

The flooding of three marsh areas around Lake Pontchartrain was investigated by examining COE tidal gage records to determine whether any large-scale trends could be established.

B. Data

The areas studied were: St. Charles marsh (using the Frenier gage), Irish Bayou marsh (using the Irish Bayou gage), and Goose Point marsh (using the Mandeville gage). In all cases the gage closest to the marsh was used, but it was assumed that the water surface between the gage and the marsh area was level.

Marsh heights are known to be between zero and two feet (0.6 m) above NGVD (National Geodetic Vertical Datum = mean sea level [MSL]) (COE Communication 1979). Therefore, in calculating the flooding time, the marsh heights were assumed to be one foot (0.3 m) above NGVD. This enabled us to make a first order investigation into the flooding of marshes surrounding the lake.

The tide gage records were analyzed by hand using the procedure outlined below. A line corresponding to a tide height of one foot (0.3 m) above NGVD was drawn along the record being analyzed. The total number of hours (for each month) that the tidal height exceeded that level was measured using a scale constructed to read in hours. In addition, the number of hours of flooding due to "storm events" was noted. Such storm events are quite noticeable on the records as large departures from the normal pattern (see Fig. 10 for an example). The frequency of flooding was also computed. In this instance, the "frequency" is defined as "the number of tidal cycles during which the marsh was flooded." Since there is a diurnal tide, the marshes would be flooded once a day if they were flooded on every tidal cycle. Hence, the upper limit to this figure is equal to the number of days in the month. This procedure was used for each of the three locations studied.

The resulting statistics giving monthly values of hours of flooding (the yearly total is also given), frequency of flooding (the yearly total is also given), and percent of flooding due to storms for each marsh area are presented in Figures 19-21.

The mean monthly level for each of the three gages were compared to ensure that there were no large discrepencies in gage data. The records were quite complete, and only a small amount of data were missing for February and March on the Frenier gage. Since the amount of data missing was small, it was ignored for this investigation.

C. Discussion and Implications

The most notable feature on the hours of flooding curves is that two peaks occur, one in May and the other in September. These peaks correspond to the mean lake level curve (Fig. 12) which also has peaks during these two months. This is to be expected because higher lake levels should result in greater marsh flooding. If the lake level pattern were to be changed by artificial means, the result could be a change in the marsh flooding regime. The effect of such a change is difficult to assess at present. In comparing the flooding data to the marsh production data collected by Cramer and Day (Chapter 9), no definite relationship appears between flooding and production. There are other factors such as nutrient loading and washing out of detritus that must be taken into account.

The flooding data also indicate that for areas within the lake proper (St. Charles and Goose Point), the yearly totals of flooding are about equal (4012 hours vs 3426 hours). The Irish Bayou area shows a significantly higher value (4760), which is to be expected because it is

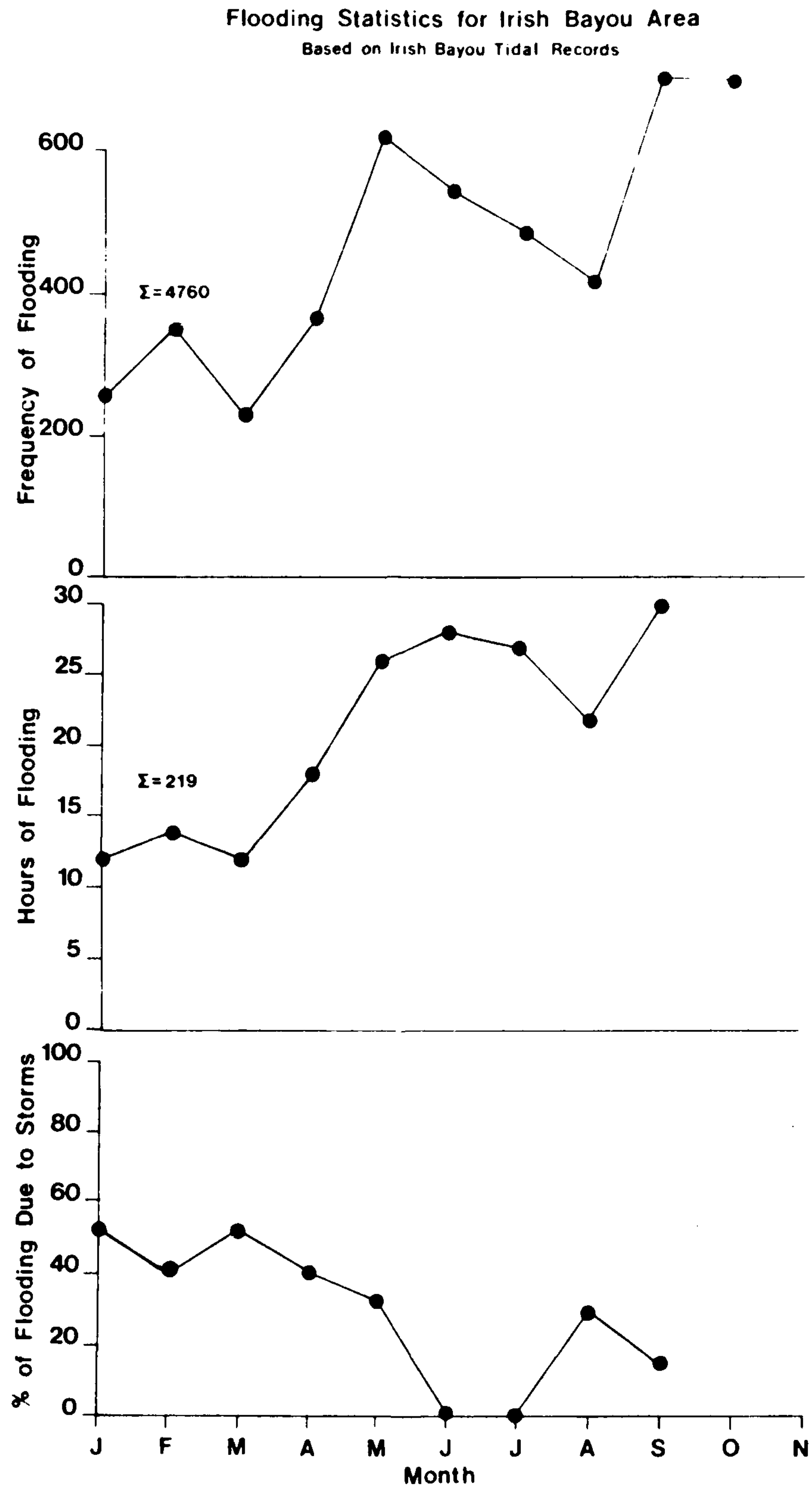


Figure 19. Plots showing, by month, (from top to bottom): hours of flooding, frequently of flooding, and percent of flooding due to storms for the Irish Bayou marsh area, over the sample year. The total hours of flooding and the total number of floodings are indicated above those plots (Based on Corps of Engineers tidal gage records--see text).

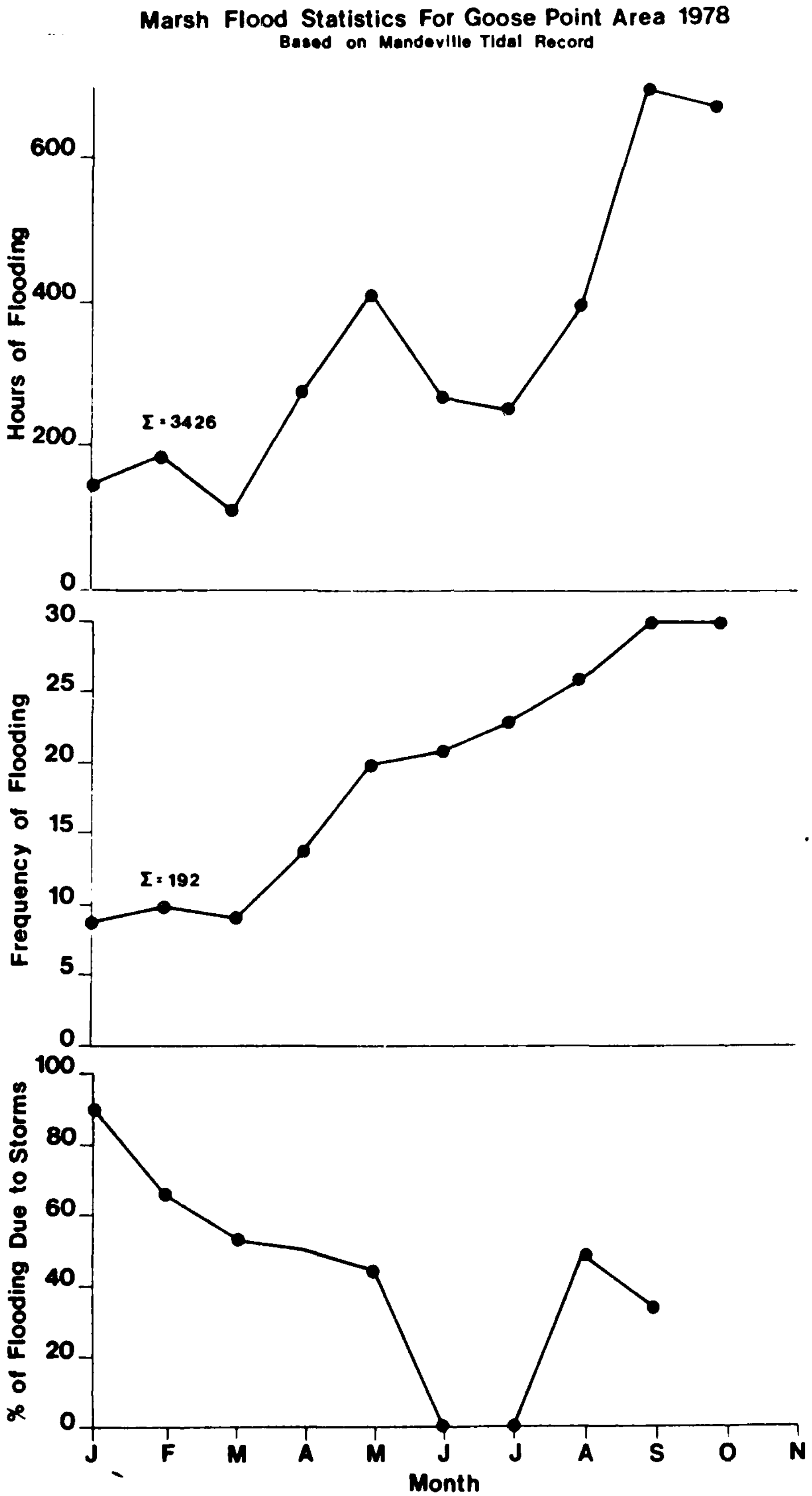


Figure 20. Plots showing (from top to bottom): hours of flooding, frequency of flooding and percent of flooding due to storms, by month, for the Goose Point marsh area, over the sample year. The total hours of flooding and the total number of floodings are indicated above those plots (Based on Corps of Engineers tidal gage records--see text.)

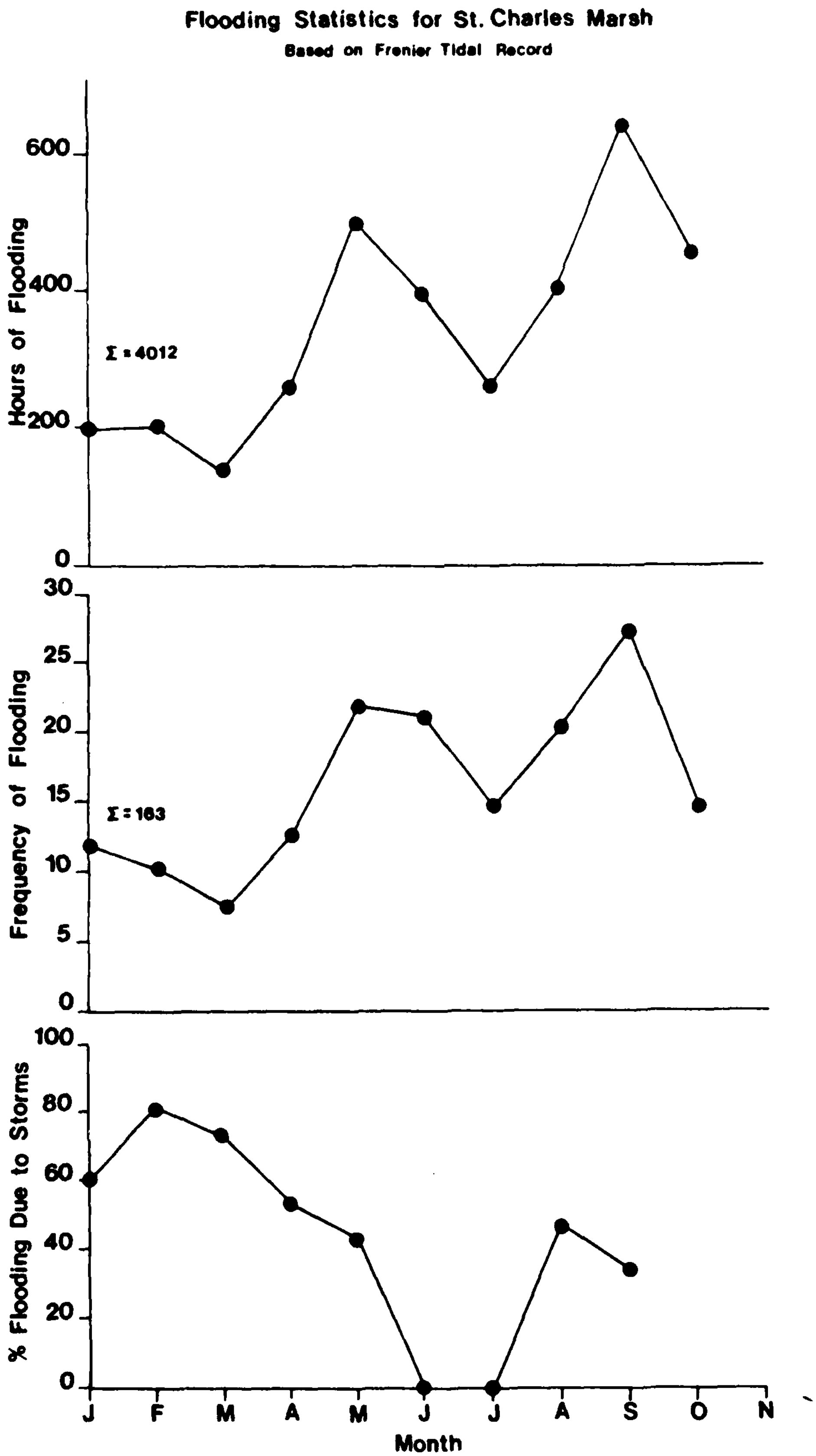


Figure 21. Plots showing, by month, 1978 (from top to bottom): hours of flooding, frequency of flooding, and percent of flooding due to storms for the St. Charles marsh area, over the sample year. The total hours of flooding and the total number of floodings are indicated above those plots (Based on Corps of Engineers tidal gage records--see text).

in a lake area dominated by the tidal passes. When the total hours of flooding for the Irish Bayou area are compared with the total hours of flooding determined by Sasser (1977) for The Rigolets area, one finds The Rigolets is greater than Irish Bayou (5550 hours as compared to 4760 hours). Again, The Rigolets marshes are in an area of greater tidal influence so one would expect a greater amount of flooding.

The total hours of flooding for the year indicate that the marshes are flooded about 50% of the time. The frequency of flooding curves show a pattern that essentially follows the hours of flooding curve.

The last curve, which shows the percent of flooding due to storms, show a seasonal trend. At all three locations, it can be seen that during the summer months of June and July, none of the flooding was due to storms. This is to be expected because large storms are usually rare during the summer months. However, during the rest of the year, winds are stronger and storms are more frequent, and these events show up on the tidal records. The data indicate that in general, storm events that either blow water into the marsh or raise the entire lake level are responsible for about 50 percent of the total flooding time.

The COE is presently conducting a survey of marsh areas around Lake Pontchartrain. The results of this survey should supply data to provide a more accurate picture of the flooding. Possibly a computer model that takes into account the actual topography of the marsh surface (the present investigation assumed a flat surface) can be constructed. This would allow for the calculation of turnover times of the water in the marsh. The present data are not accurate enough to make any detailed calcuations of turnover times.

VI. Bonnet Carre Floodway Study

During April of 1979, the Bonnet Carre Floodway was opened by the COE. During the time the floodway was open, several cruises were made to study the effects of the opening. The main purpose of the cruises was to map the plume through the use of three separate parameters: temperature, conductivity, and suspended load.

Temperature and conductivity maps were made using the flow-thru system discussed previously. Water samples were collected from the flow-thru system for suspended load analysis. Anchor stations were also established for the collection of nutrient and heavy metal samples as well as for the collection of triplicate samples for suspended load analysis.

In addition to the water samples taken for suspended load, a Bausch and Lomb Spectronic-20 spectrophotometer was connected to the flow-thru system to map turbidity. This system was marginally successful and provided data useful in defining trends but not quantitatively acceptable.

Samples collected for suspended load were analyzed by filtering a known volume of water (usually 100 to 200 ml) through a pre-weighed, dry, "millipore" filter (0.45 μ). The filters were allowed to dry, then were re-weighed to get the total amount of solids. In addition to the actual samples, some filters were used as "blanks" (100 ml of distilled water was filtered through them) in order to correct for changes in filter weight. The results were expressed as mg/l dry weight. Statistical analyses performed on triplicate samples indicate that the average error in the suspended load data is $\pm$ 5% (at the 95% level).

This report is concerned only with the conductivity, temperature, and suspended load patterns. The nutrient and heavy metals are being analyzed by the benthos group. A separate report (in another publication) will discuss these data.

Data from the floodway study are presented in Appendix 4. Figure A4-1 shows a time history of discharge from the floodway (from COE) along with notes pertaining to the operation of the floodway. It can be seen that the floodway was open for 38 days and released a total volume of 1.6×10^{10} m^3 into the lake. This is a volume that is slightly greater than the total volume of the lake. The 1979 opening is comparable in magnitude of flow and duration to the 1950 opening (based on data from Gunter [1953]).

Average suspended load concentrations for various locations around the lake are shown in Figure A4-2. It can be seen that normal concentrations are about 10-30 mg/l. Figure A4-3 shows the cruise track and sample locations from the cruise of April 26, 1979. Data from this cruise are shown in Figures A4-4 thru A4-7. Current data (A4-4) indicate that the plume headed in an easterly direction along the southern shore of the lake. Temperature (A4-5), conductivity (A4-6), and suspended load (A4-7) maps show a similar circulation pattern. A conductivity of 1.0 mmho/cm, a temperature of about 22°C, and a suspended load concentration of about 60 mg/l define the edge of the plume. As the plume enters the lake, it appears to displace the normal lake waters by "pushing" them northward, thus forming an east-to-west boundary about 10 km from the south shore. Perhaps it is this boundary effect that forces the plume to travel in an easterly direction. Waters from the plume had a

temperature of 5°C lower than ambient, with a conductivity of about 3 mmhos/cm lower than ambient. Suspended loads in the plume were 60-160 mg/l.

The cruise track and sample locations from the cruise of May 9, 1979 are shown in Figure A4-8. Data from this cruise are shown in Figures A4-9 thru A4-11. All of the parameters show the same general patterns and values as observed on the April 26 cruise. However, on this date the plume was much larger and covered about half to two-thirds of the lake (it was confined to the southwest corner on April 26). This probably represents the maximum extent of the plume because the Corps began to close the floodway on May 7, 1979.

The last sampling cruise took place on May 15, 1979. During this cruise only suspended load samples were collected. As can be seen in Figure A4-12, the suspended load values have returned to normal, except for a point right at the floodway. This is expected; the discharge on this day was about a third of what it was on the May 5 cruise (see Figure A4-1).

The physical data collected during the floodway opening indicate that enough water was released into the lake over a period of about 60 days to completely replace the total volume. This replacement time is approximately six times faster than the time it would normally take with the average river flow into the lake. In addition, the data indicate that approximately one-half to two-thirds of the total lake area was affected by the plume. It appears as though the north shore area was not affected.

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APPENDIX 1 - CURRENT SPEED AND DIRECTION PROFILE PLOTS

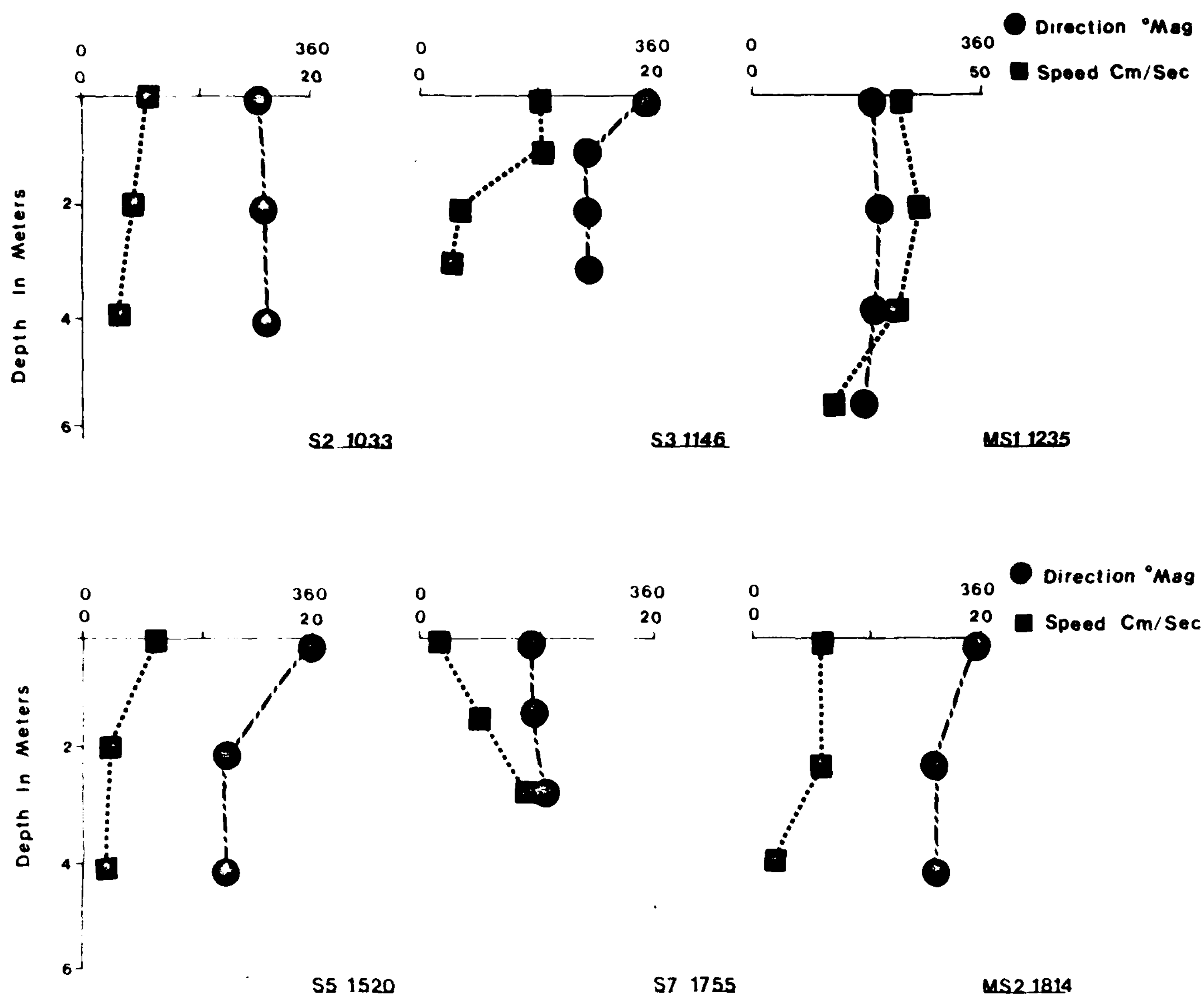

Figure A1-1. Current speed (cm/sec) and direction (°Mag) profile plots for Lake Pontchartrain, LA from March 15, lo78. The station location and time are indicated at the lower right of each plot.

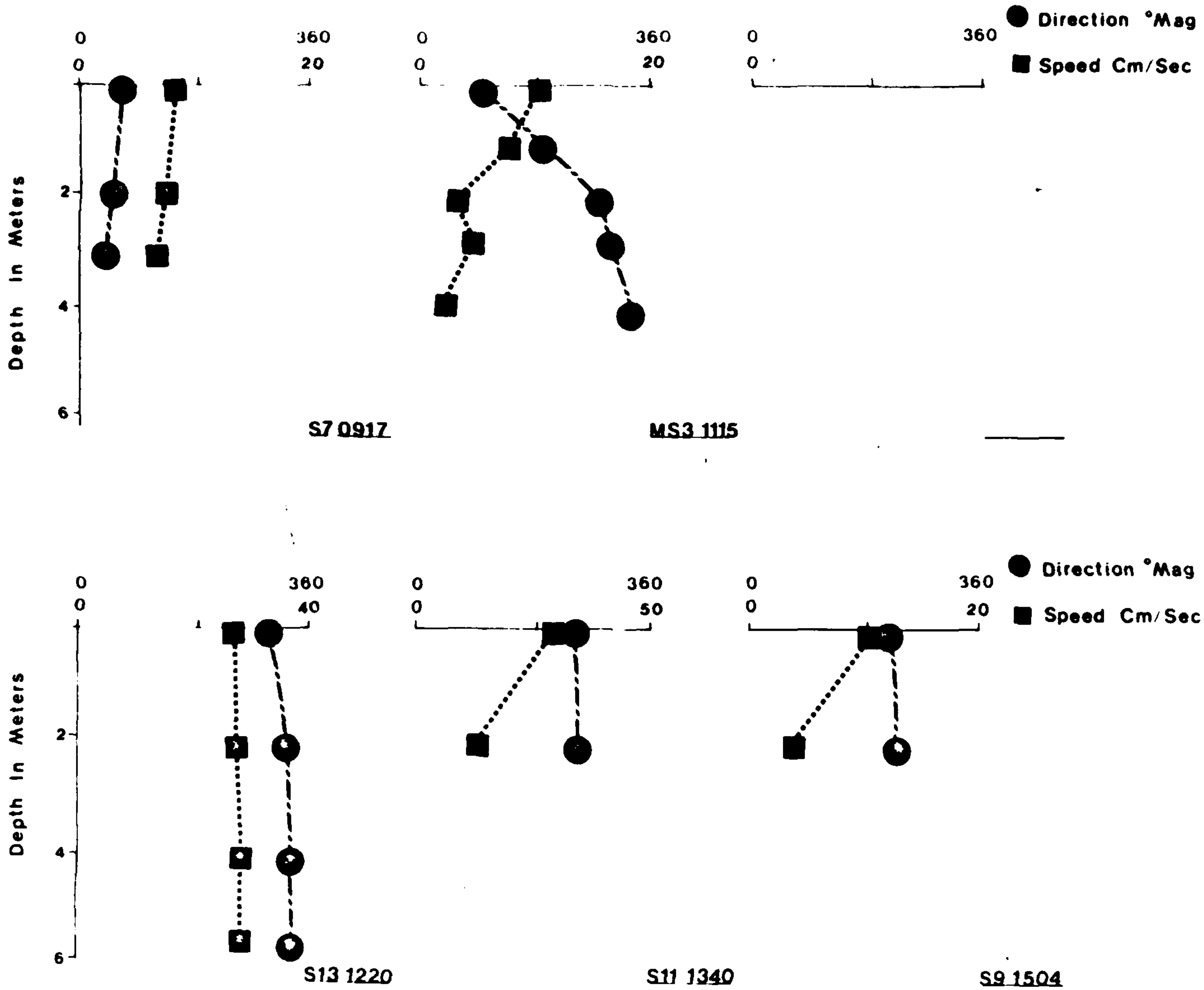

Figure A1-2. Current speed (cm/sec) and direction (°Mag) profile plots for Lake Pontchartrain, LA from April 25, 1978 (top) and April 28, 1978 (bottom). The station location and time are indicated at the lower right of each plot.

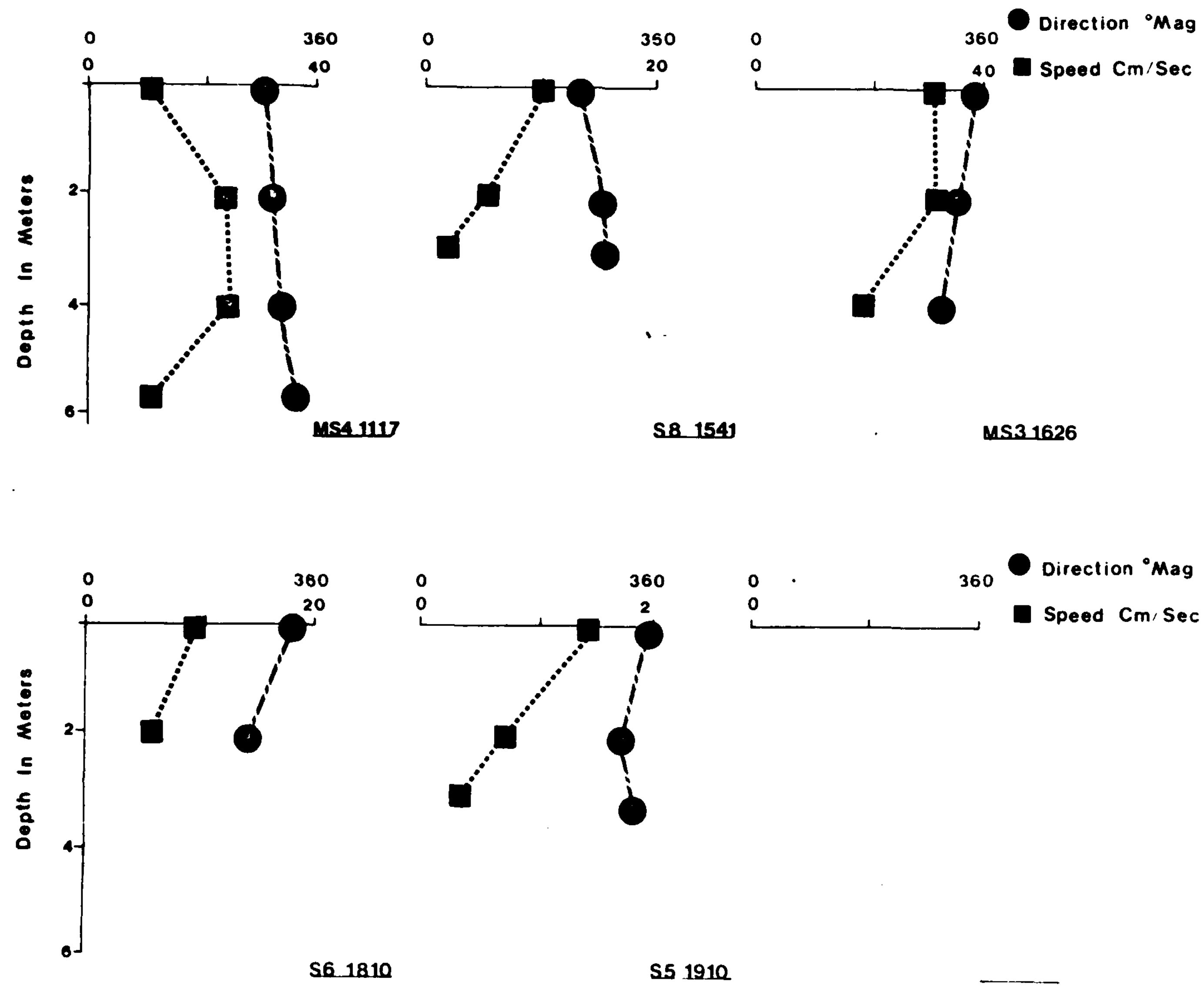

Figure A1-3. Current speed (cm/sec) and direction (°Mag) profile plots for Lake Pontchartrain, LA from April 28, 1978. The station location and time are indicated at the lower right of each plot.

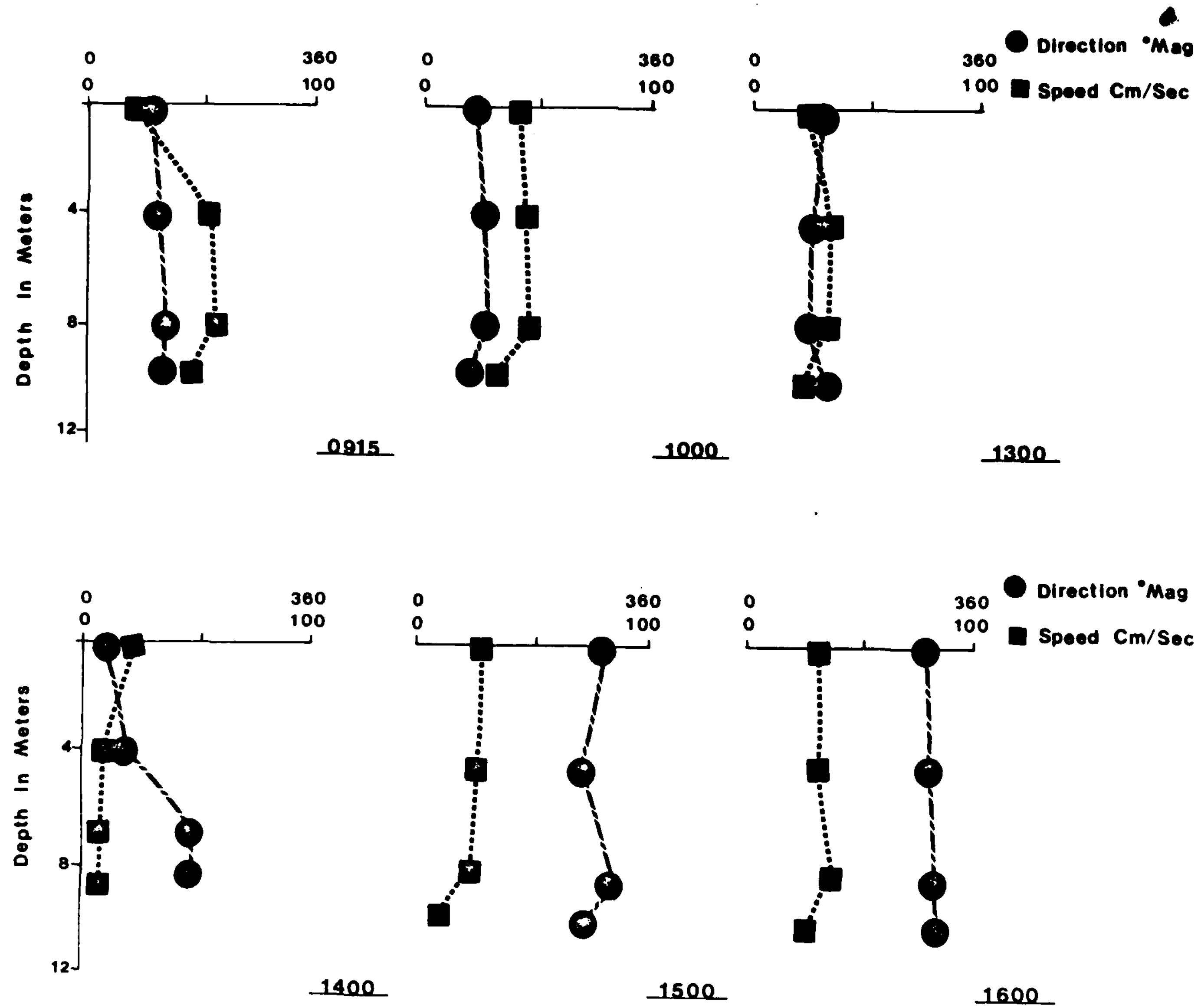

Figure A1-4. Current speed (cm/sec) and direction (°Mag) profile plots at Station MS1 in Lake Pontchartrain, LA on June 20, 1978. The time of each sample is indicated at the lower right of each plot.

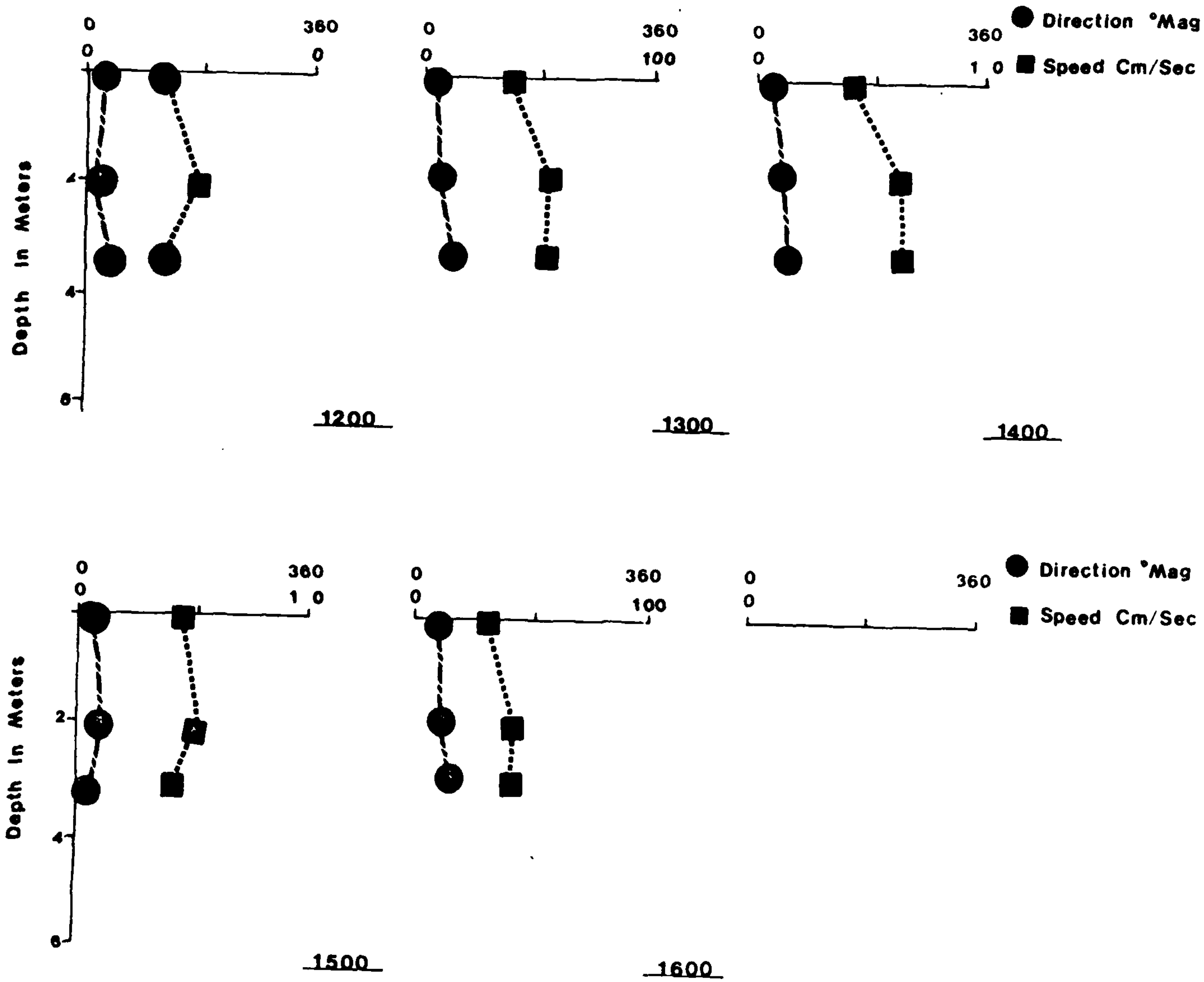

Figure A1-5. Current speed (cm/sec) and direction (°Mag) profile plots at Station MS3 in Lake Pontchartrain, LA on June 22, 1978. The time of each sample is indicated at the lower right of each plot.

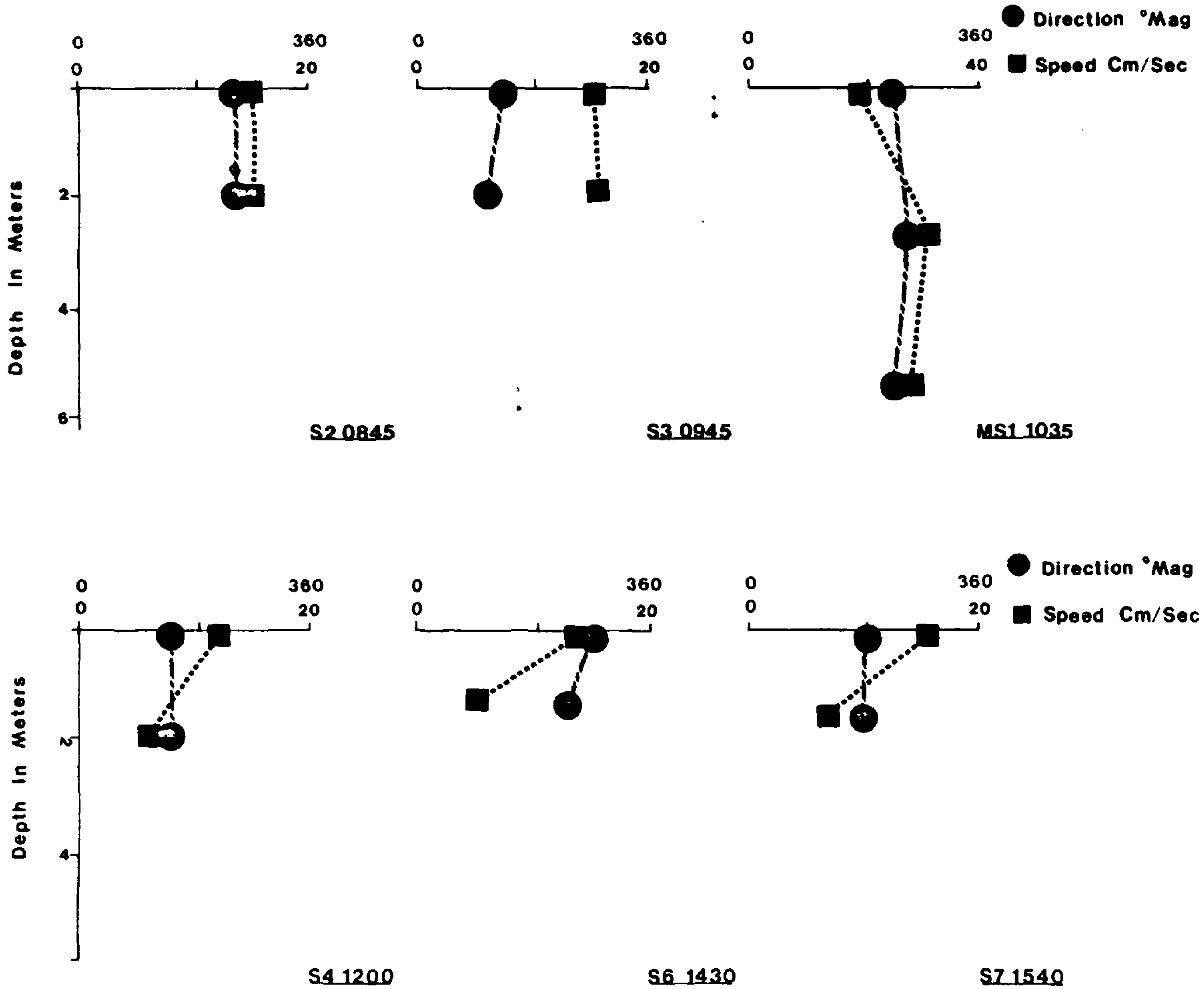

Figure A1-6. Current speed (cm/sec) and direction (°Mag) profile plots of Lake Pontchartrain, LA from October 10, 1978. The station location and time are indicated in the lower right of each plot.

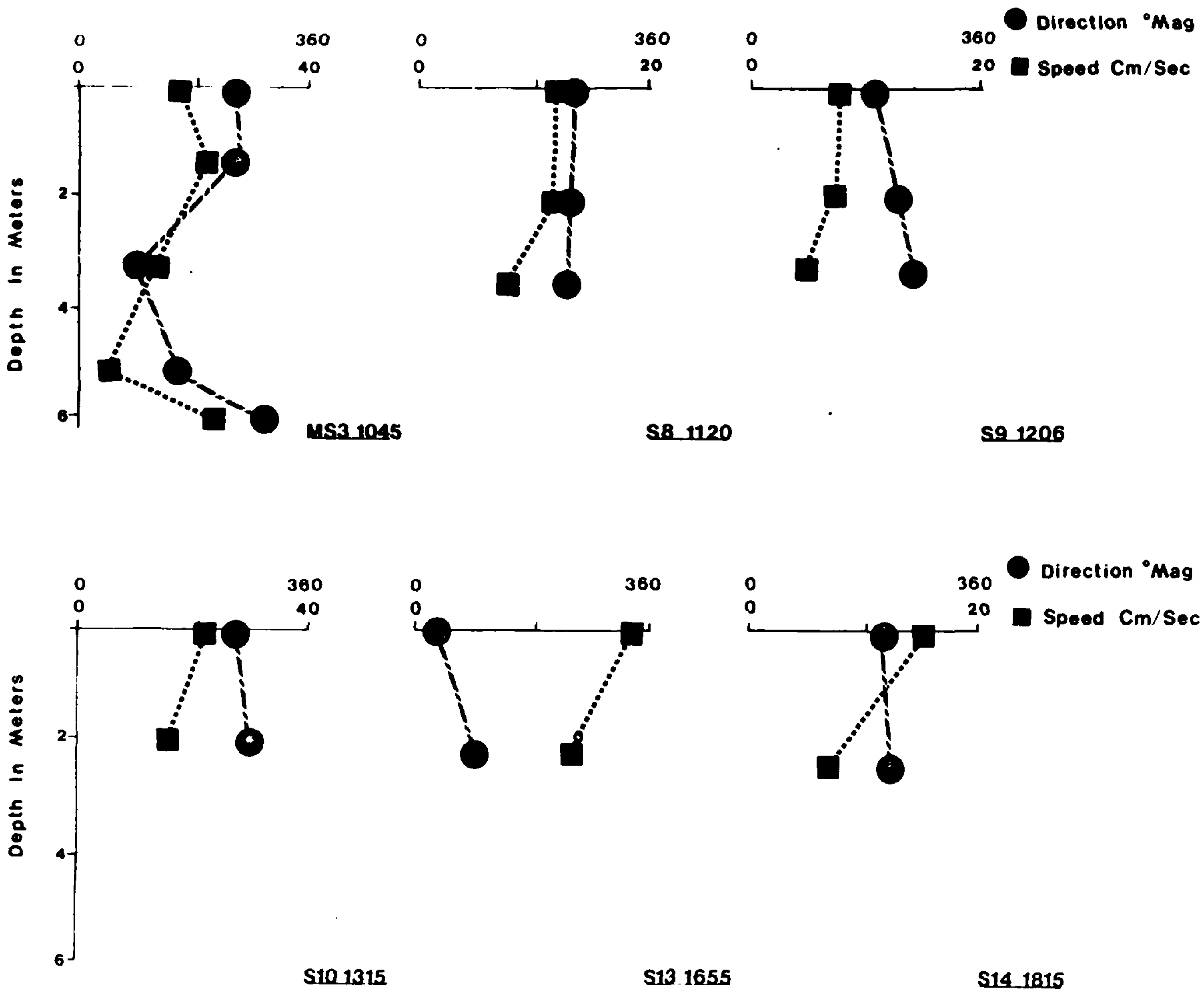

Figure A1-7. Current speed (cm/sec) and direction (°Mag) profile plots of Lake Pontchartrain, LA from October 11, 1978. The station location and time are indicated in the lower right of each plot.

APPENDIX 2 - CONDUCTIVITY AND TEMPERATURE PROFILE PLOTS

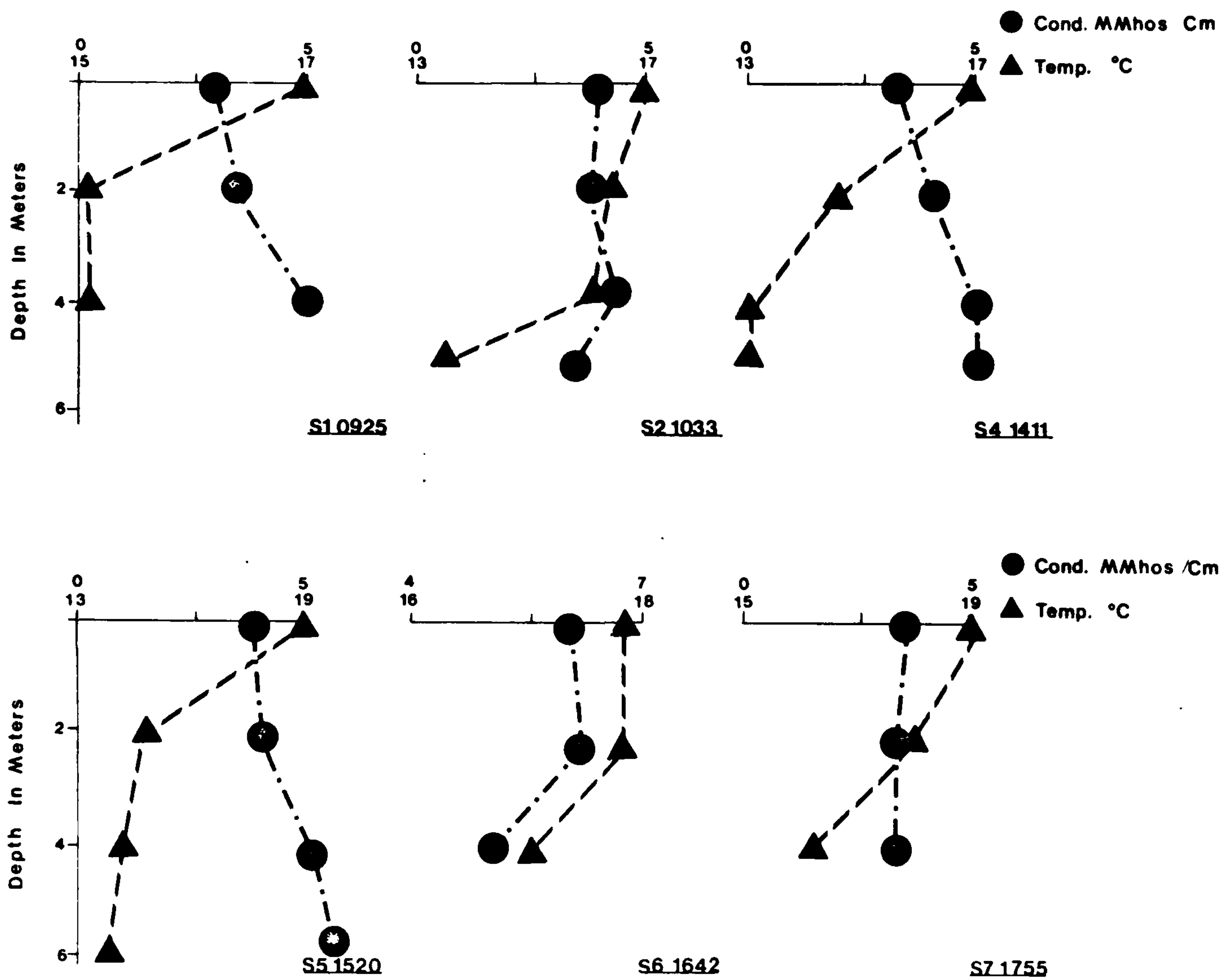

Figure A2-1. Conductivity (mmhos/cm) and temperature (°C) profile plots of Lake Pontchartrain, LA from March 15, 1978. The station location and time are indicated in the lower right of each plot.

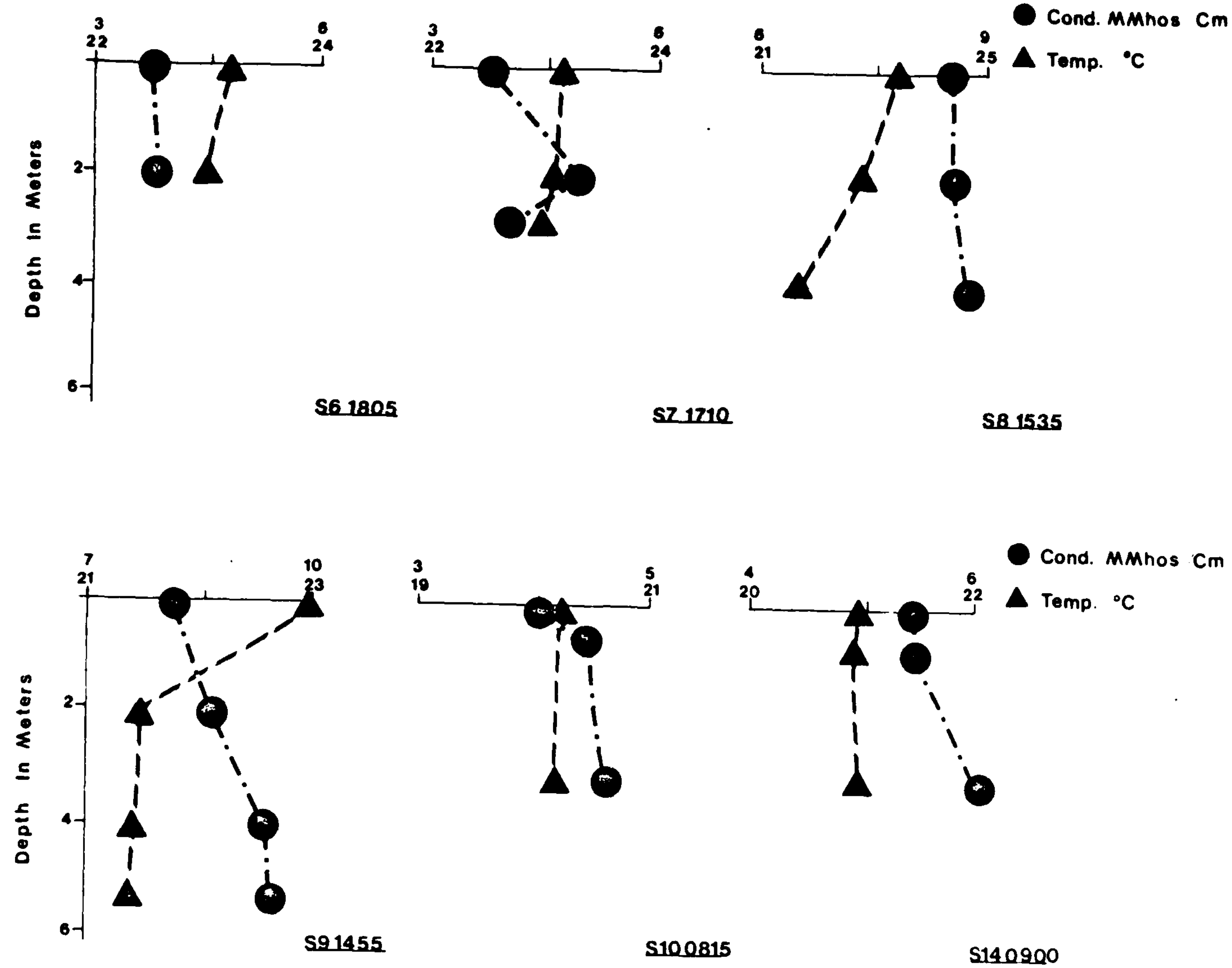

Figure A2-2. Conductivity (mmhos/cm) and temperature (^{o}C) profile plots of Lake Pontchartrain, LA from March 15, 1978. The station location and time are indicated in the lower right of each plant.

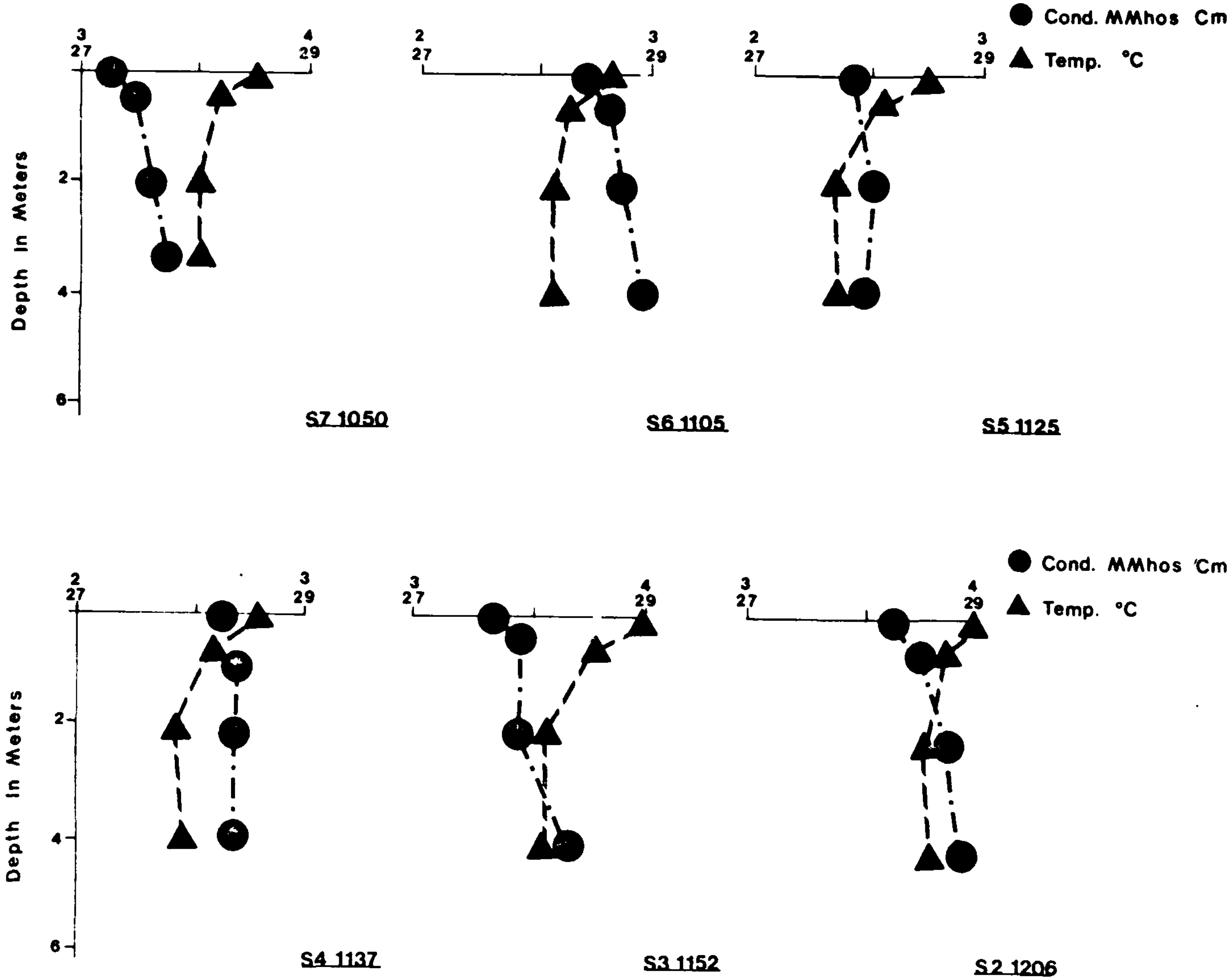

Figure A2-3. Conductivity (mmhos/cm) and temperature (^{O}C) profile plots of Lake Pontchartrain, LA from May 30, 1978. The station location and time are indicated in the lower right of each plot.

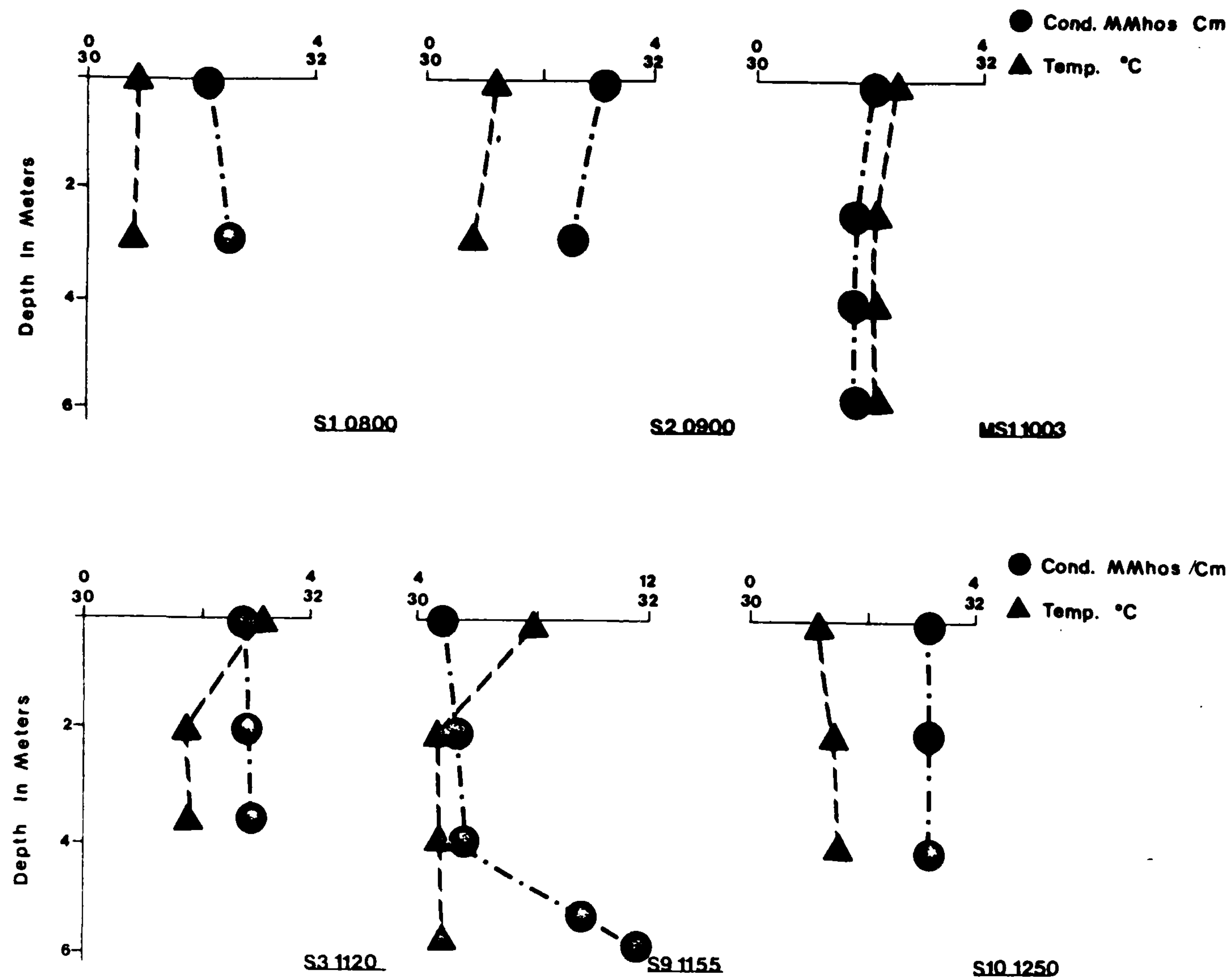

Figure A2-4. Conductivity (mmhos/cm) and temperature (^{o}C) profile plots of Lake Pontchartrain, LA from July 18, 1978 (S1, S2, MS1, S3) and July 20, 1978 (S9, S10). The station location and time are indicated in the lower right of each plot.

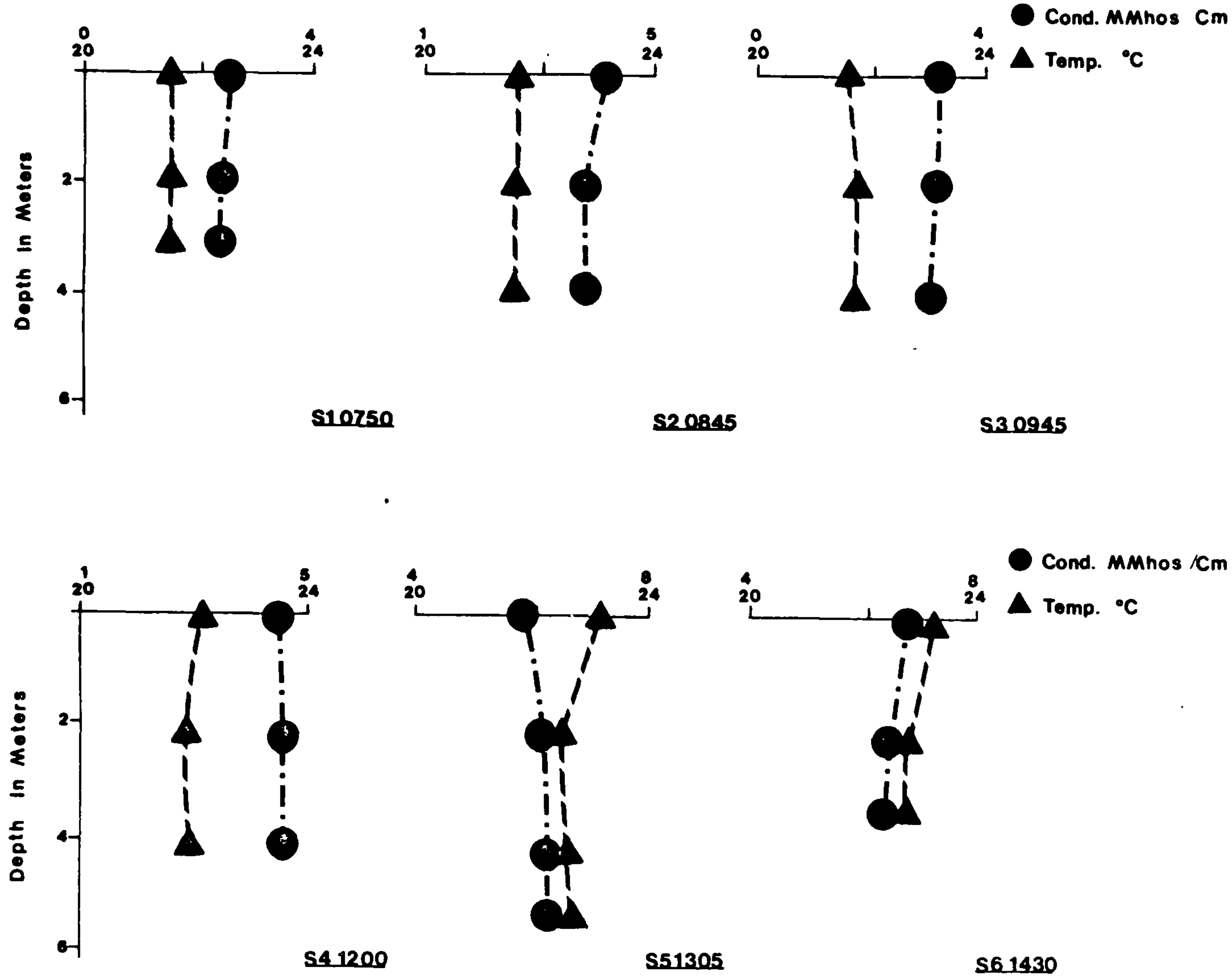

Figure A2-5. Conductivity (mmhos/cm) and temperature (^{O}C) profile plots of Lake Pontchartrain, LA from October 10, 1978. The station location and time are indicated in the lower right of each plot.

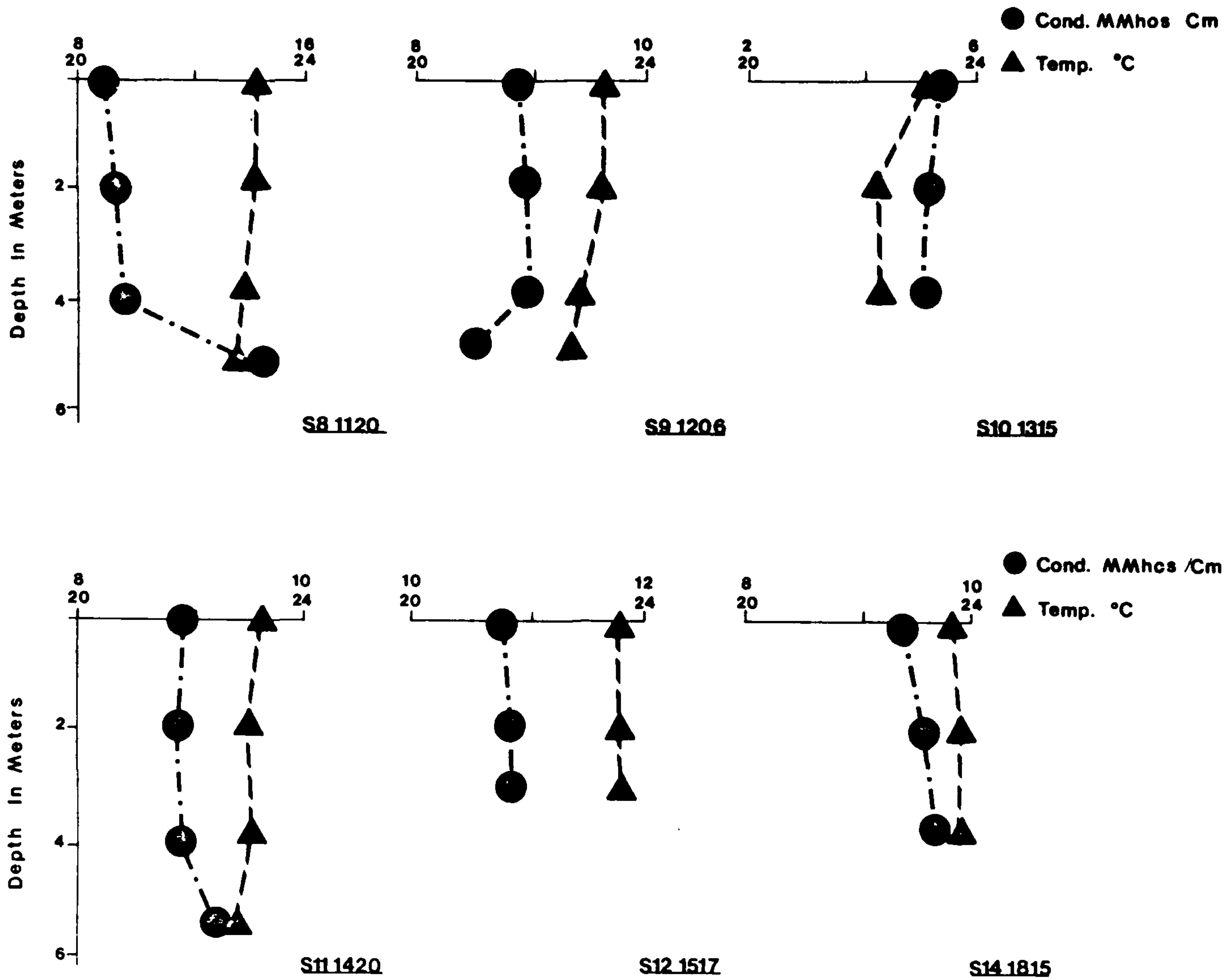

Figure A2-6. Conductivity (mmhos/cm) and temperature (^{o}C) profile plots of Lake Pontchartrain, LA from October 11, 1978. The station location and time are indicated in the lower right of each plot.

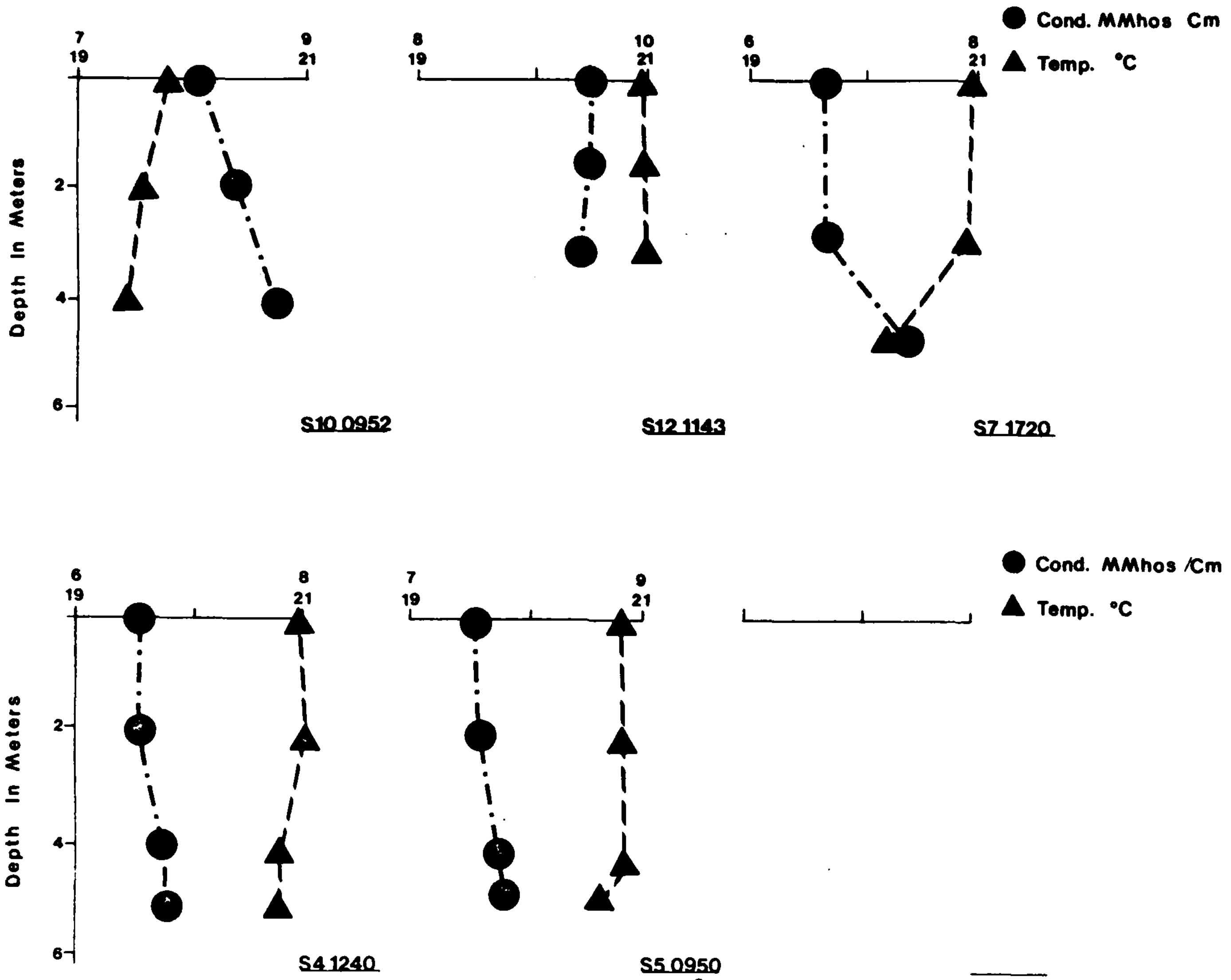

Figure A2-7. Conductivity (mmhos/cm) and temperature (°C) profile plots of Lake Pontchartrain, LA from November 13, 1978 (top) and November 14, 1978 (bottom). The station location and time are indicated in the lower right of each plot.

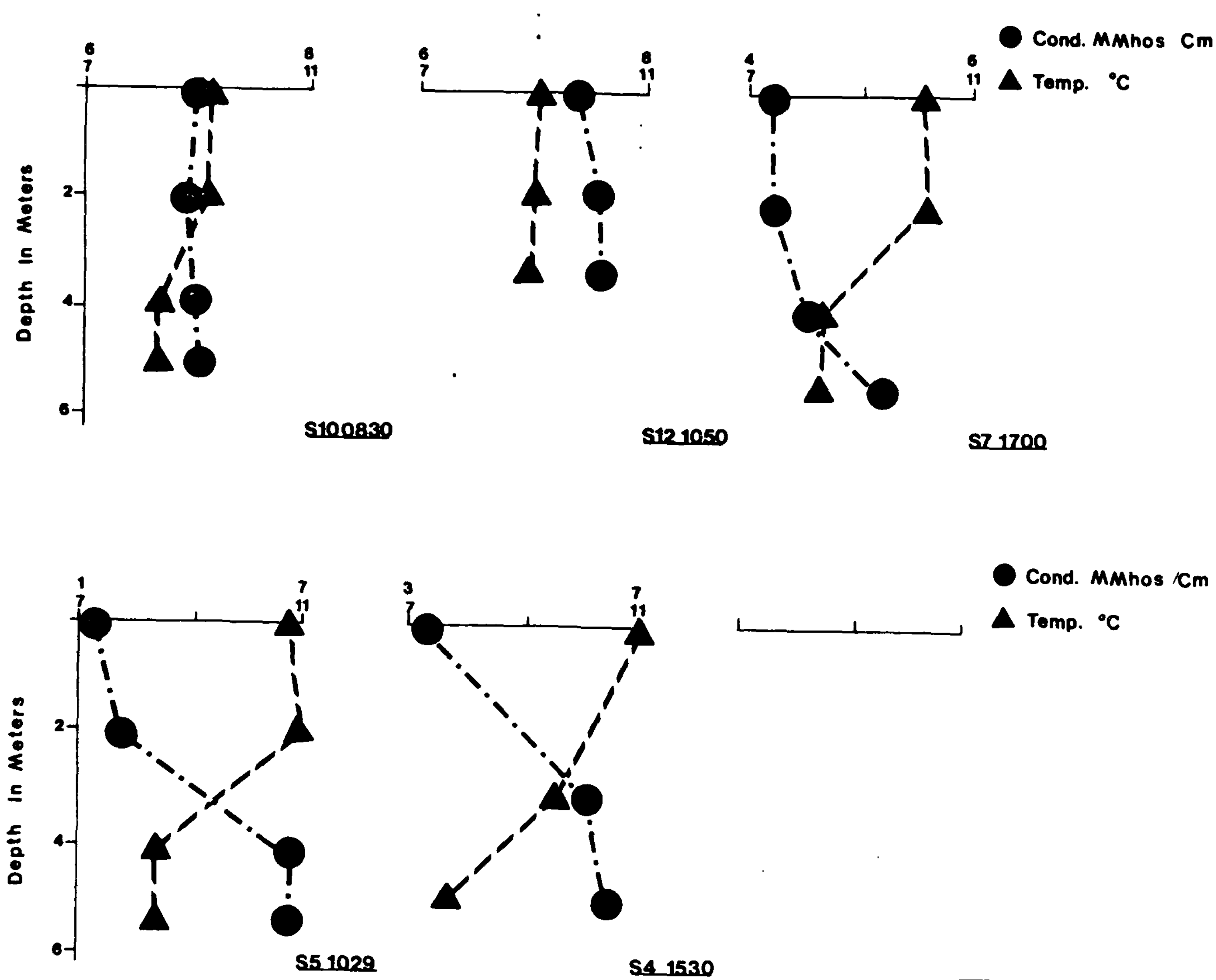

Figure A2-8. Conductivity (mmhos/cm) and temperature (°C) profile plots of Lake Pontchartrain, LA from February 13, 1979 (top) and February 14, 1979 (bottom). The station location and time are indicated in the lower right of each plot.

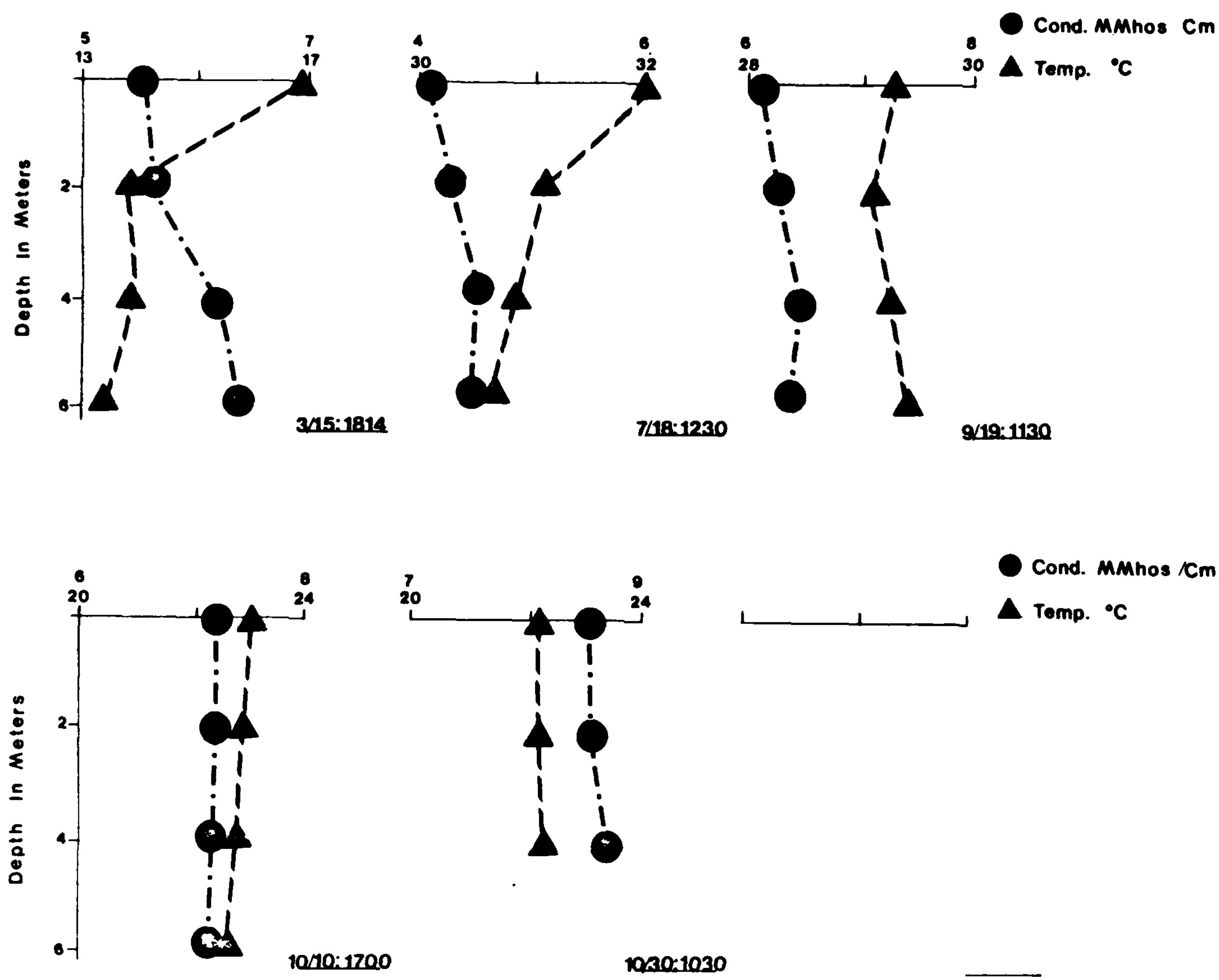

Figure A2-9. Conductivity (mmhos/cm) and temperature (^{O}C) profile plots of Lake Pontchartrain, LA from Station MS2. The date and time of each plot are indicated in the lower right of each plot.

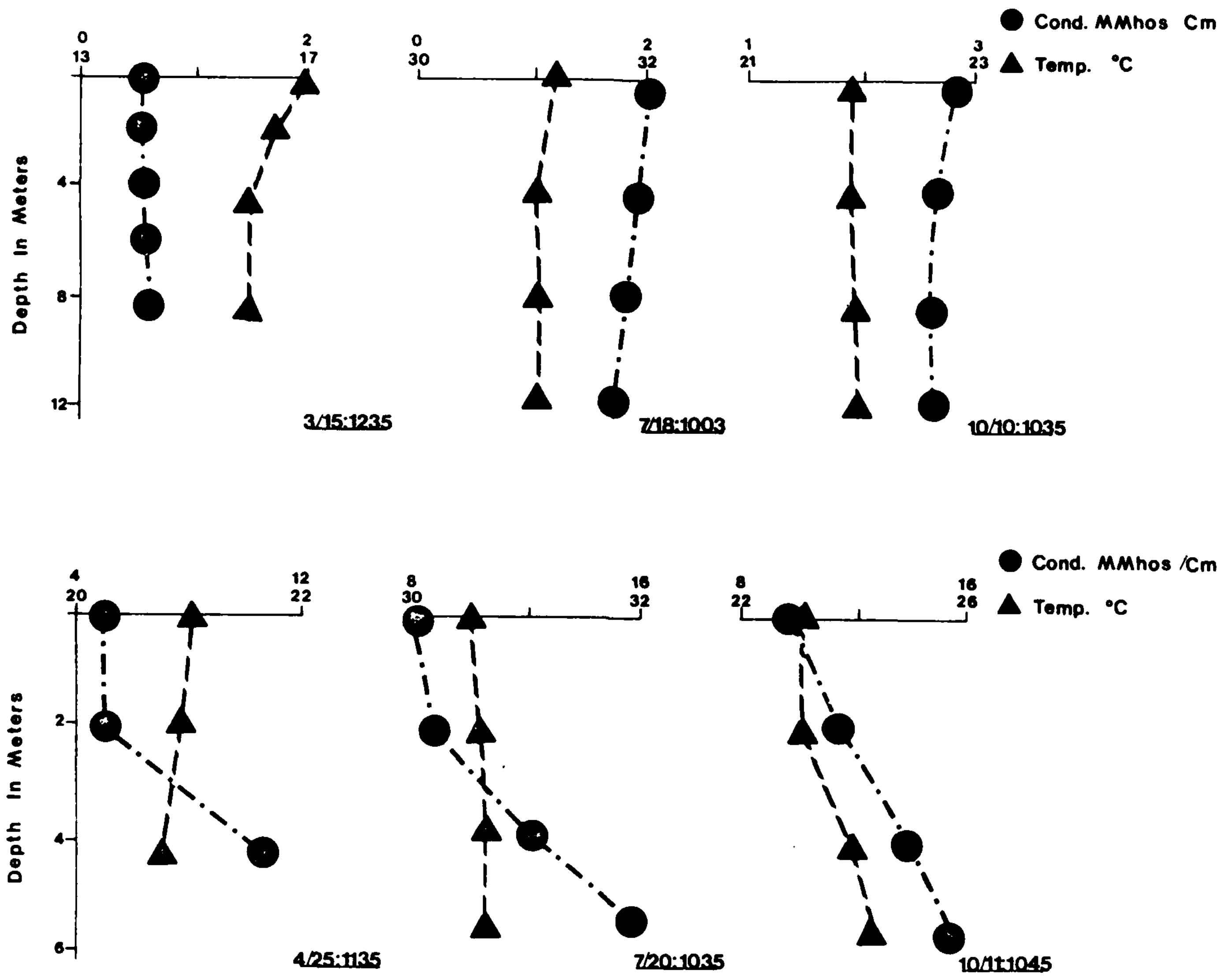

Figure A2-10. Conductivity (mmhos/cm) and temperature (^{o}C) profile plots of Lake Pontchartrain, LA from Station MS1 (top) and MS2 (bottom). The date and time of each plot are indicated in the lower right of each plot.

APPENDIX 3 - SURFACE MAPS OF CONDUCTIVITY AND TEMPERATURE

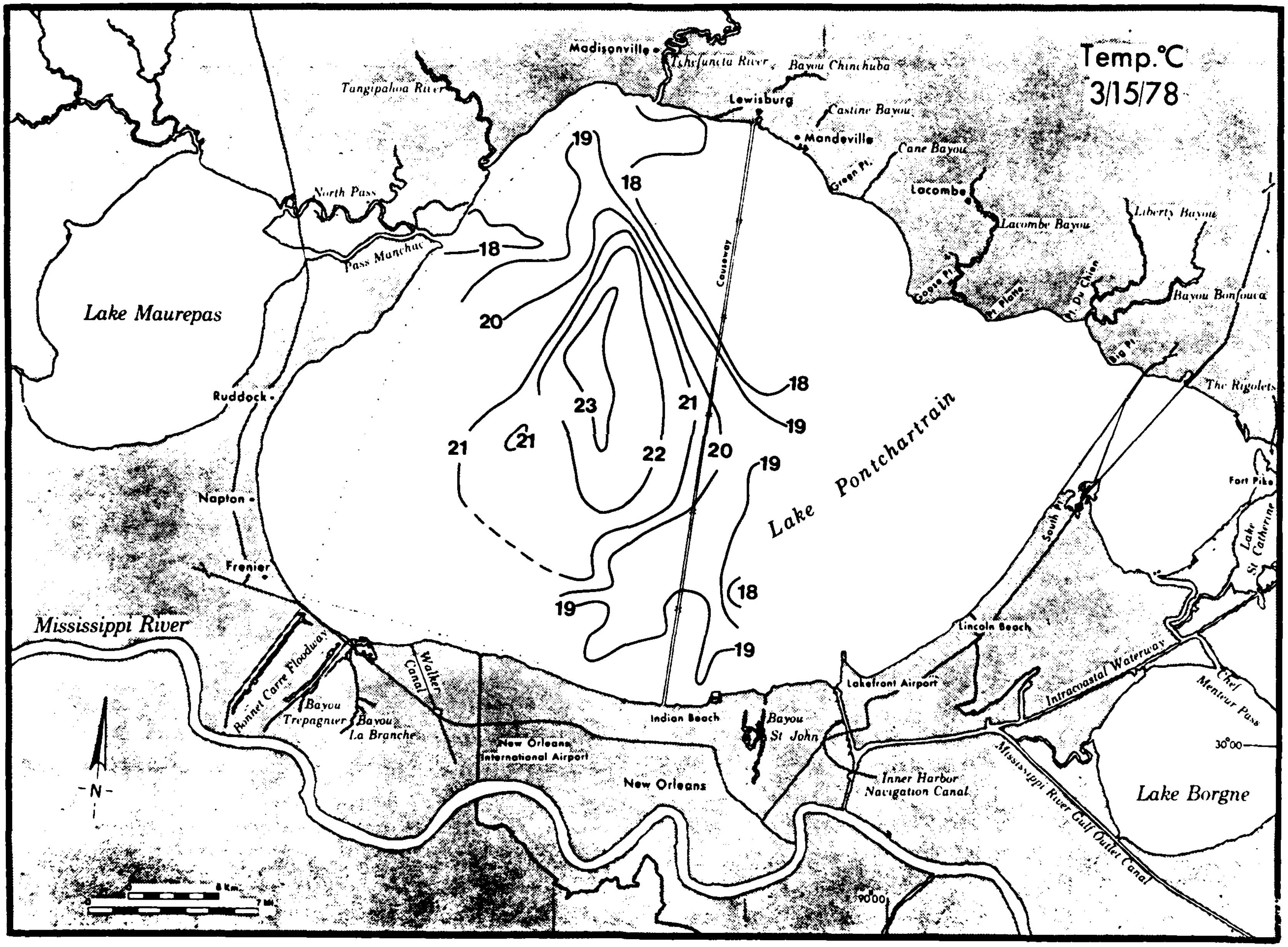

Figure A3-1. Surface temperature map (°C) of Lake Pontchartrain, LA, from cruise of March 15, 1978.

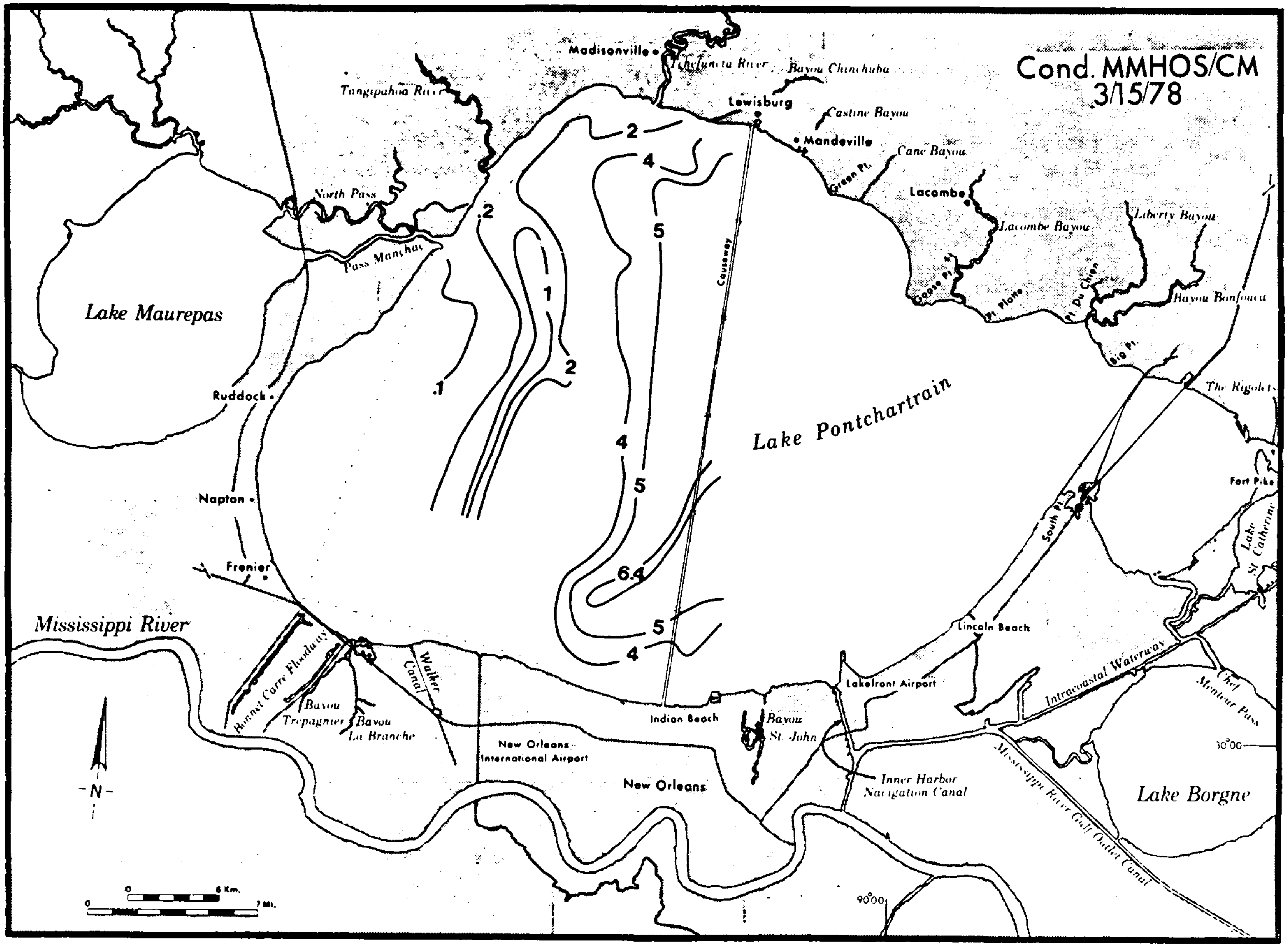

Figure A3-2. Surface conductivity map (mmhos/cm) of Lake Pontchartrain, LA, from cruise of March 15, 1978.

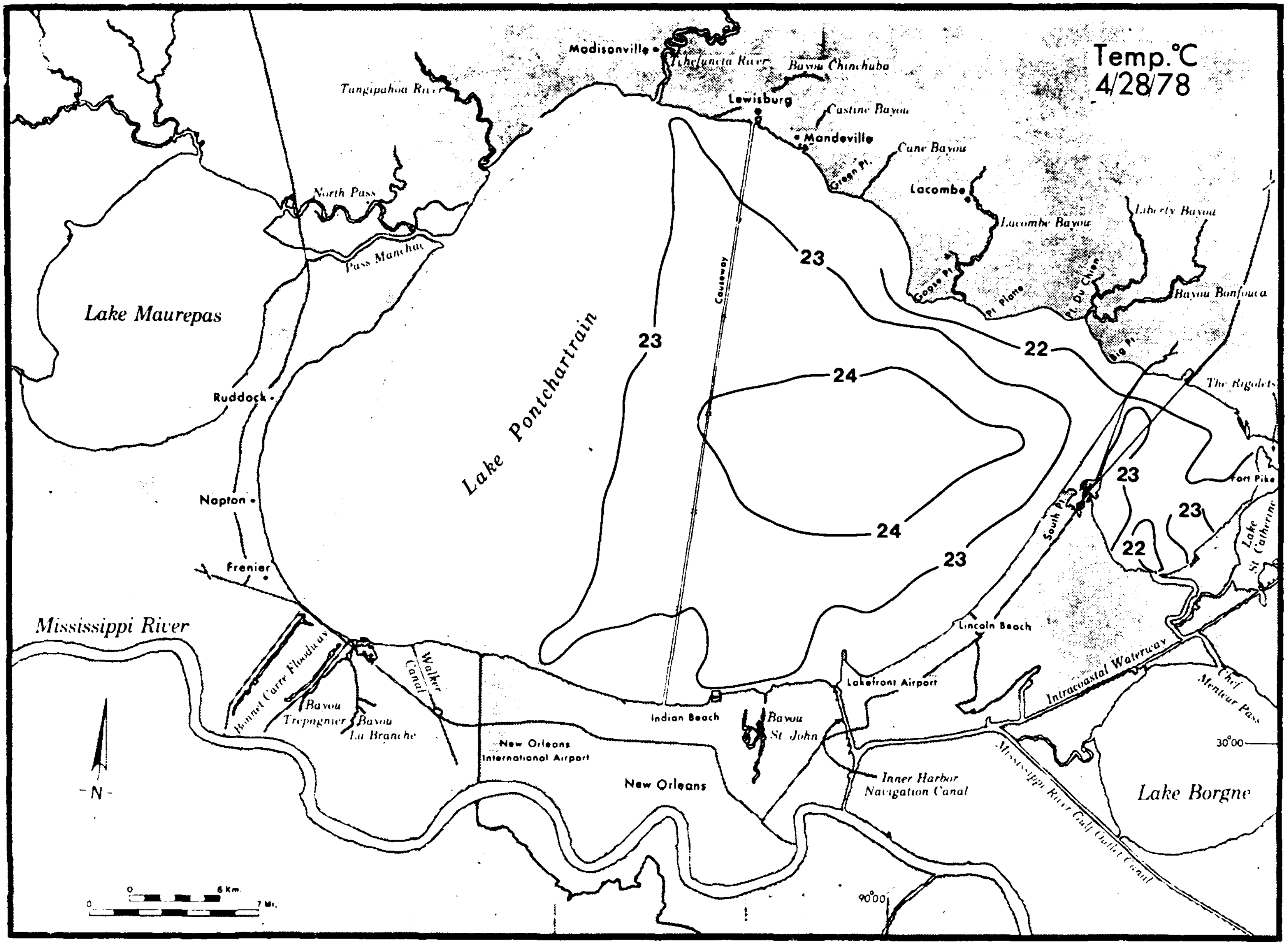

Figure A3-3. Surface temperature map (°C) of Lake Pontchartrain, LA, from cruise of April 28, 1978.

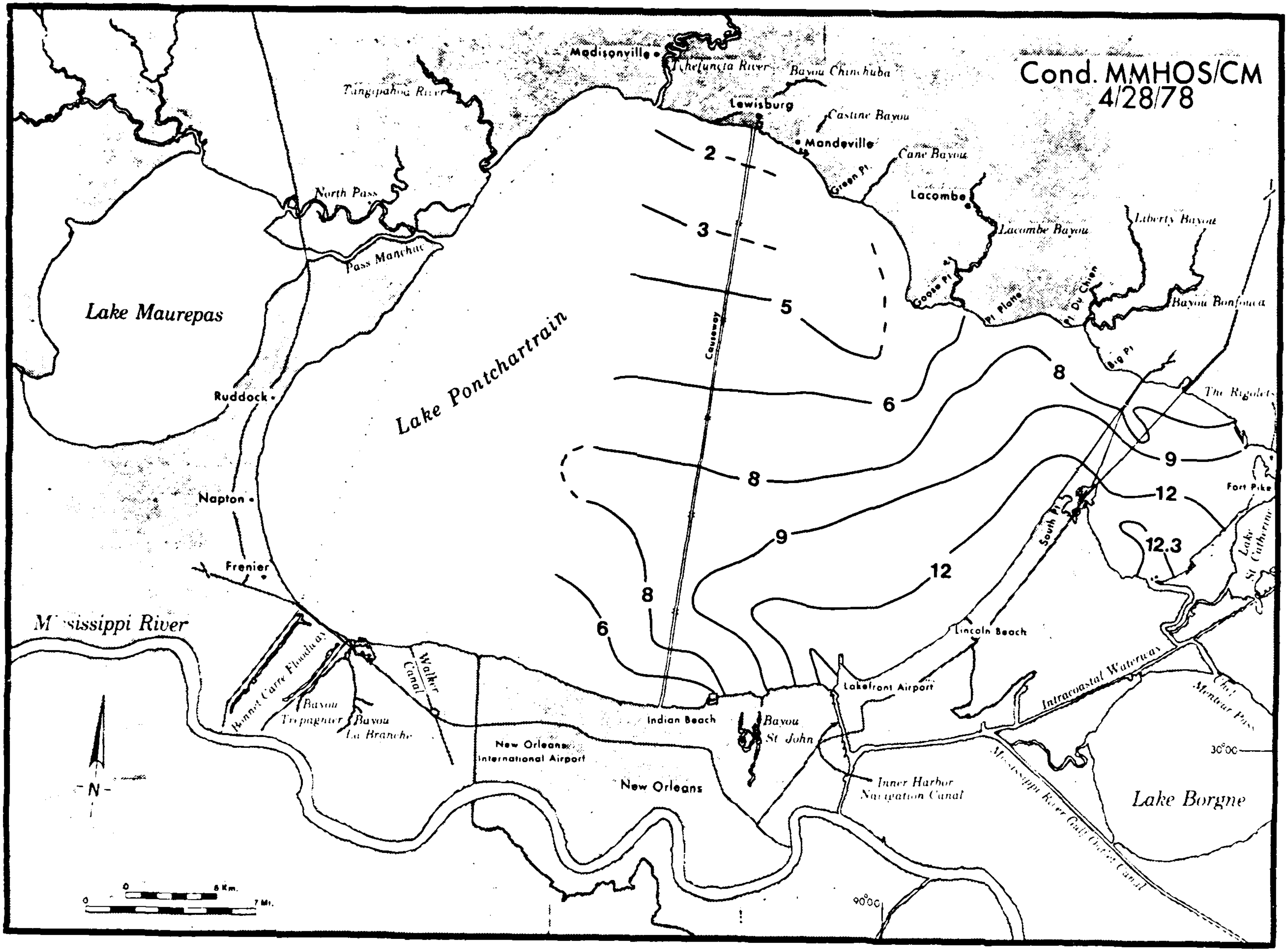

Figure A3-4. Surface conductivity map (mmhos/cm) of Lake Pontchartrain, LA, from cruise of April 28, 1978.

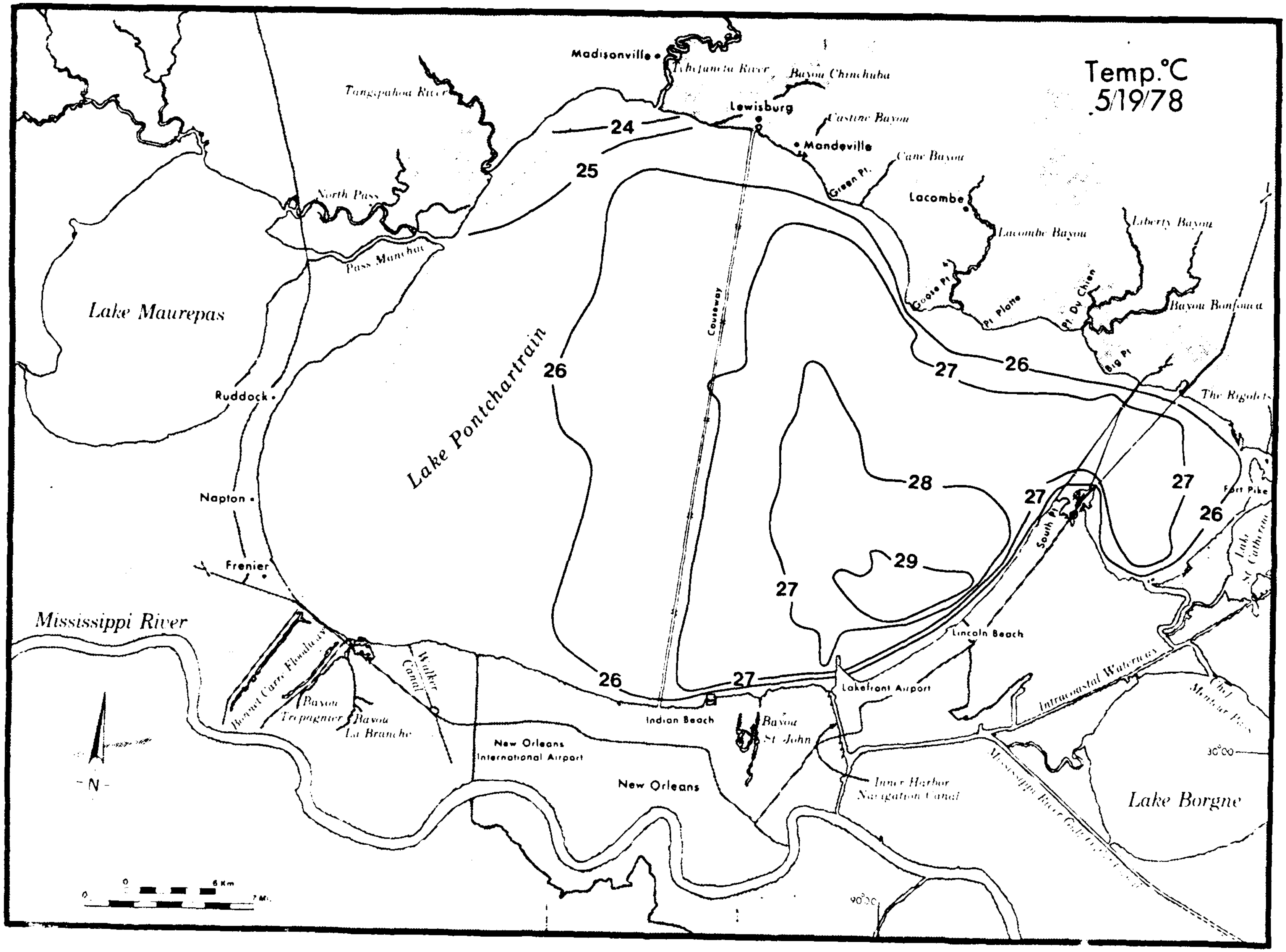

Figure A3-5. Surface temperature map (°C) of Lake Pontchartrain, LA, from cruise of May 19, 1978.

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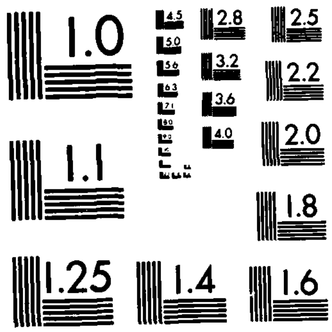


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

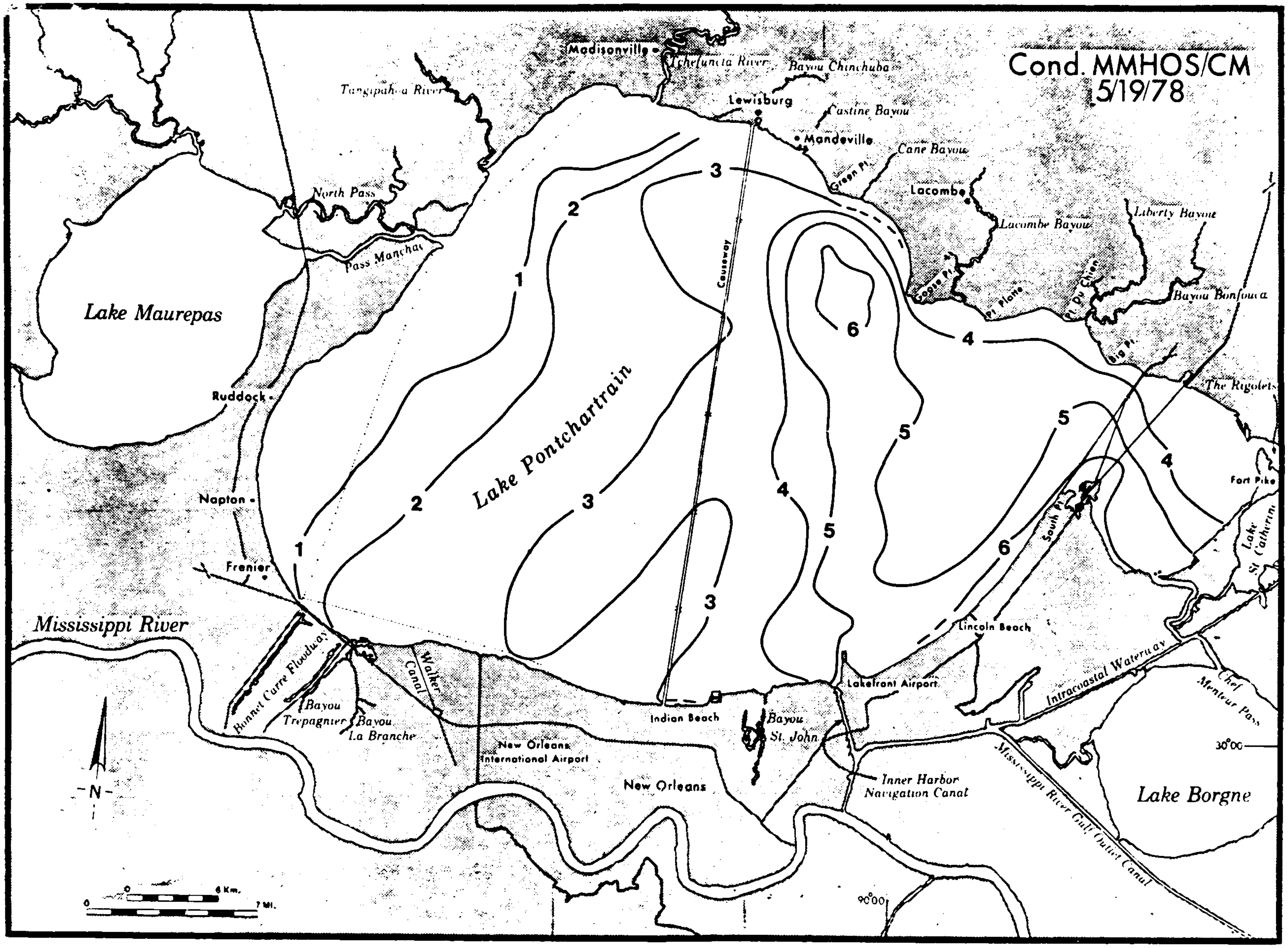


Figure A3-6. Surface conductivity map (mmhos/cm) of Lake Pontchartrain, LA, from cruise of May 19, 1978.

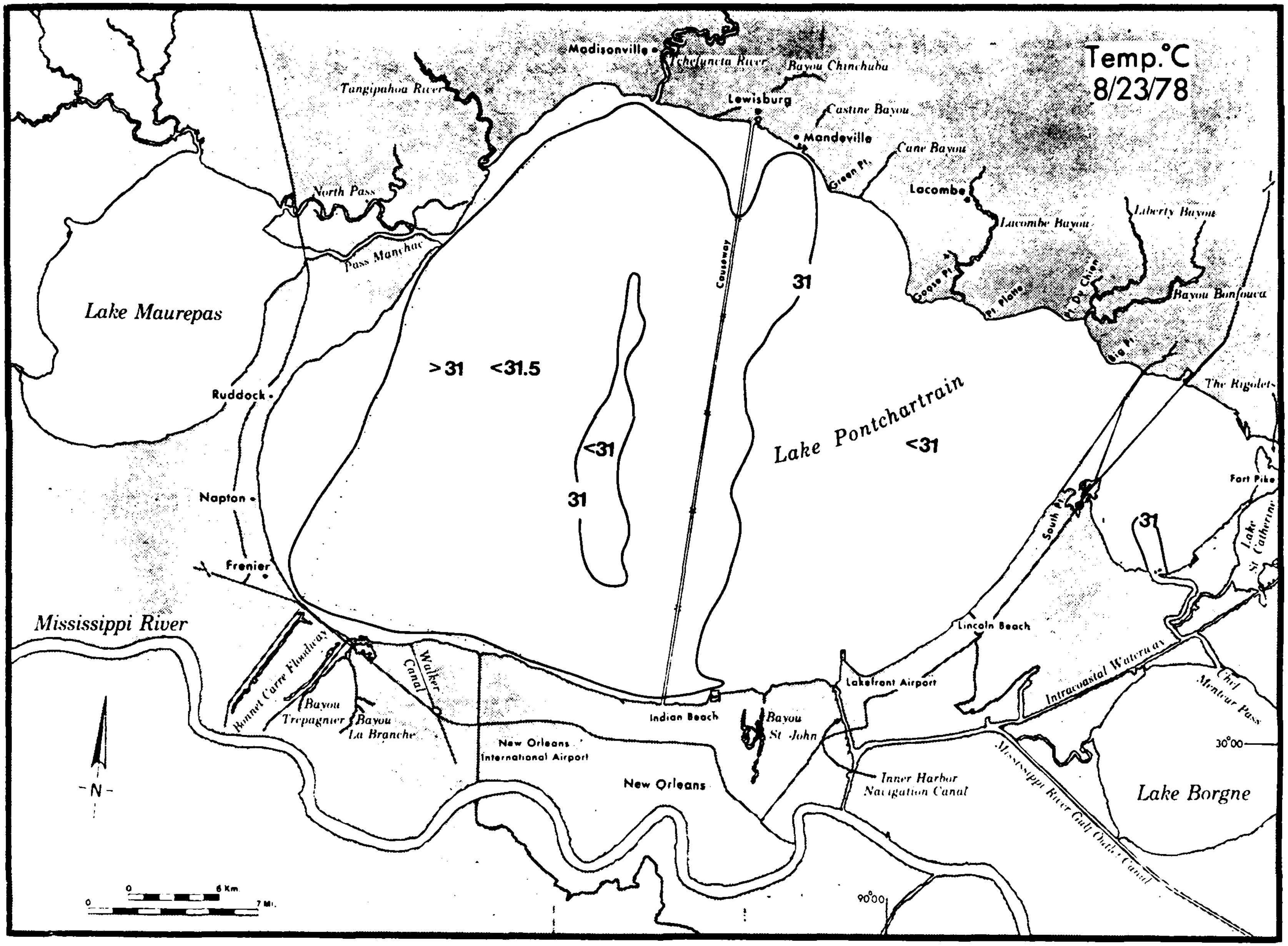


Figure 43-7. Surface temperature map (°C) of Lake Pontchartrain, LA from cruise of August 23, 1978.

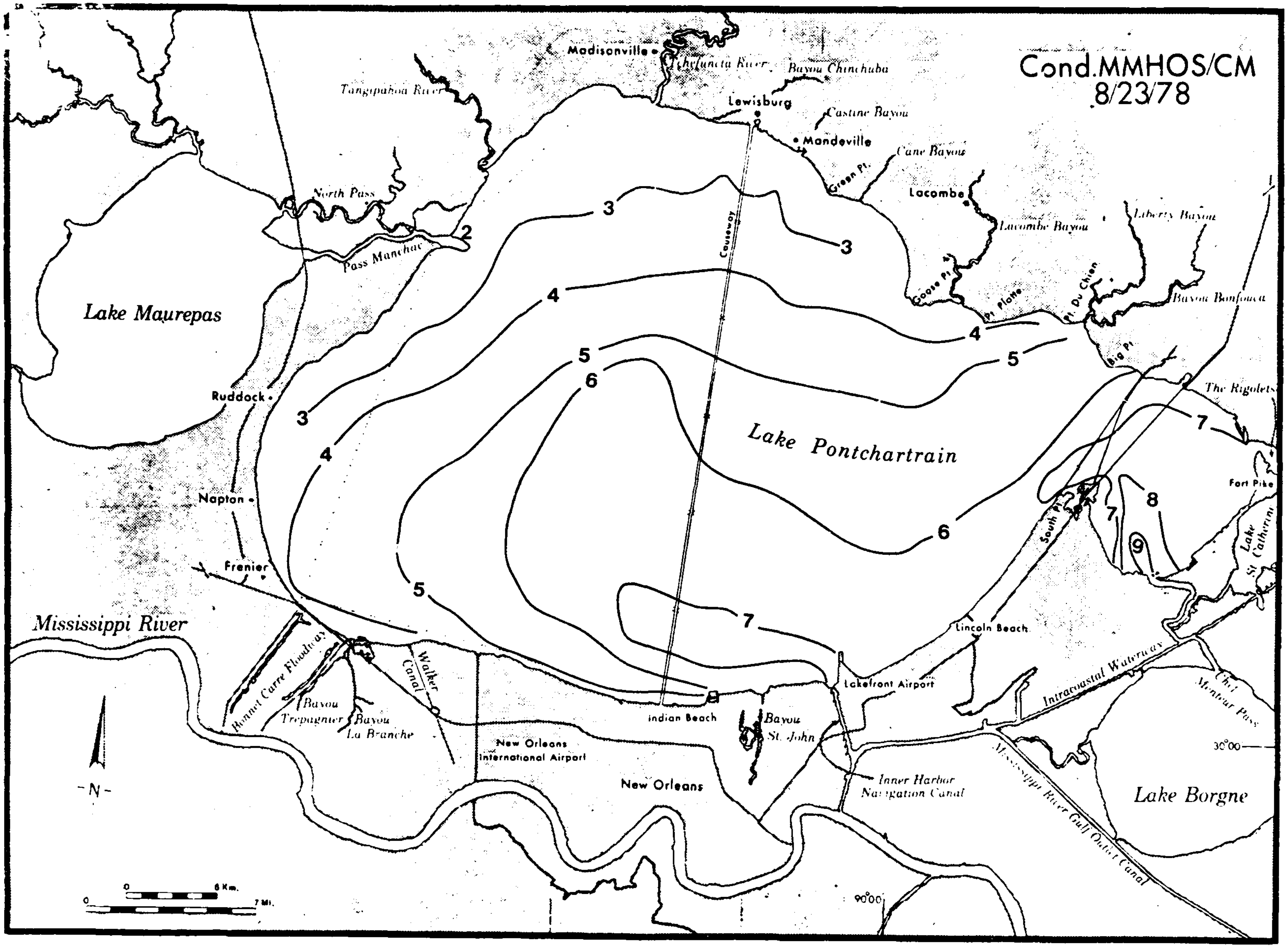


Figure A3-8. Surface conductivity map (mmhos/cm) of Lake Pontchartrain, LA, from cruise of August 23, 1978.

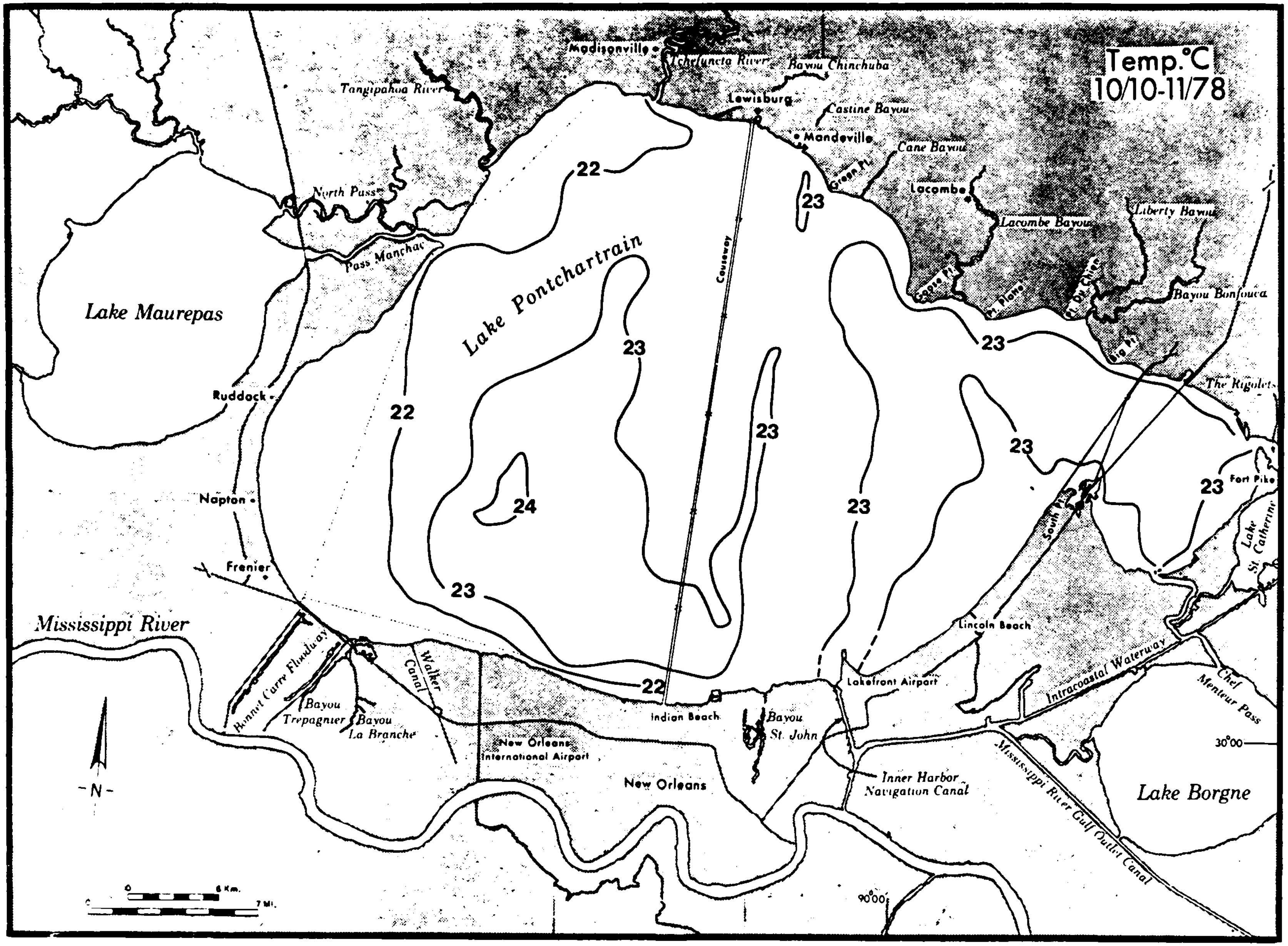


Figure A3-9. Surface temperature map (°C) of Lake Pontchartrain, LA from cruises of October 10-11, 1978

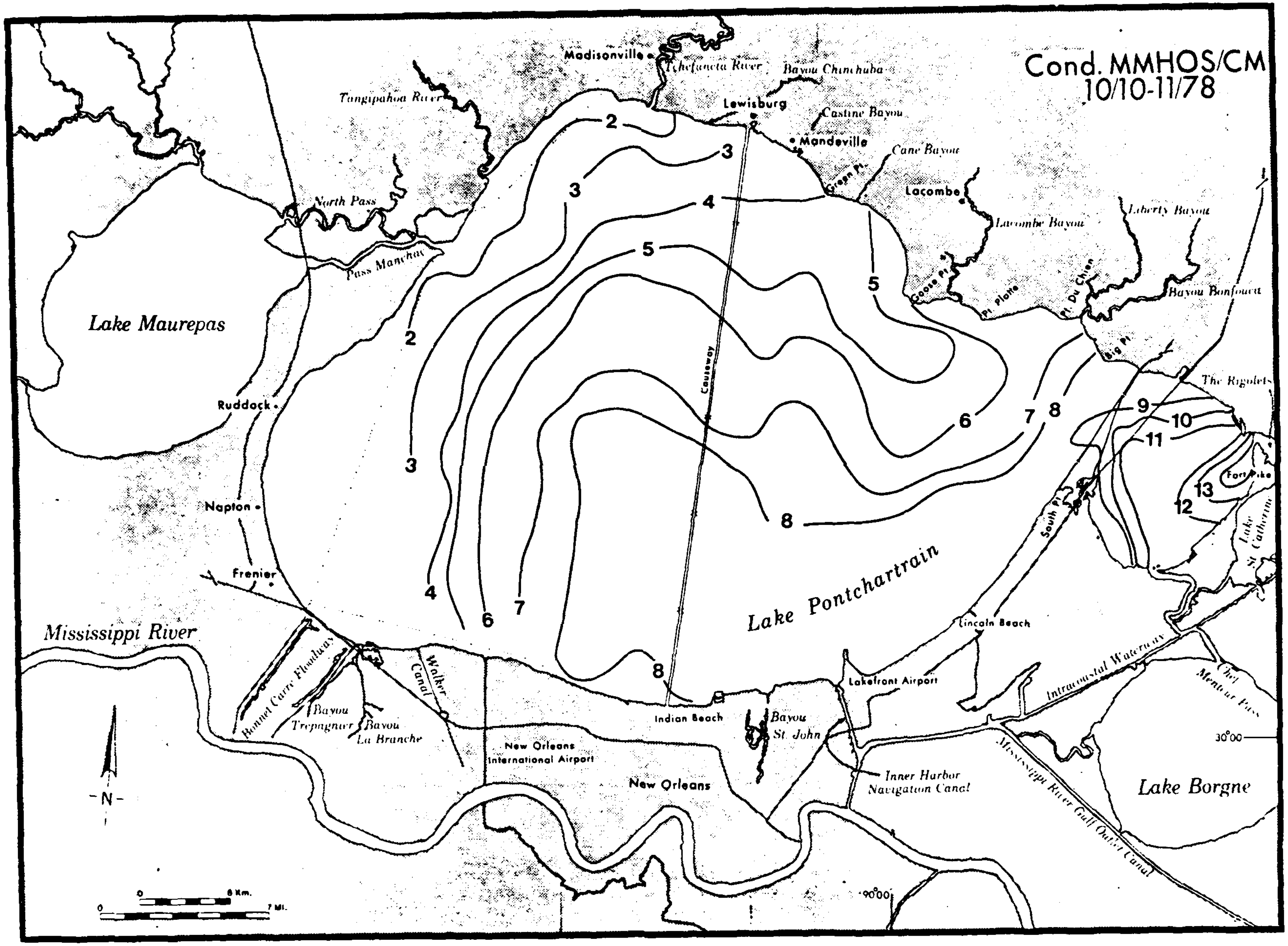


Figure A3-10. Surface conductivity map (mmhos/cm) of Lake Pontchartrain, LA, from cruises of October 10-11, 1978.

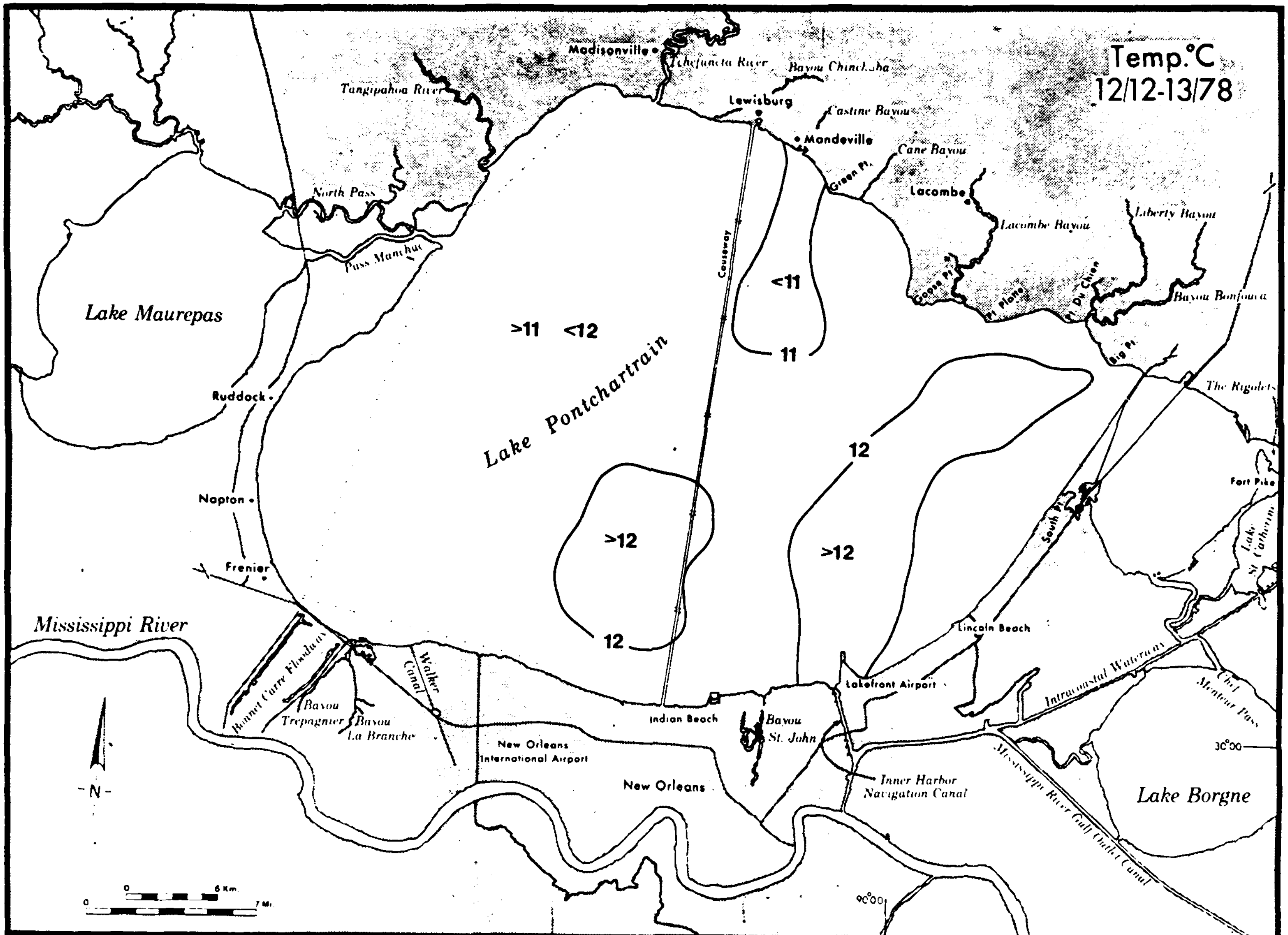


Figure A3-11. Surface temperature map (°C) of Lake Pontchartrain, LA from cruises of December 12-13, 1978.

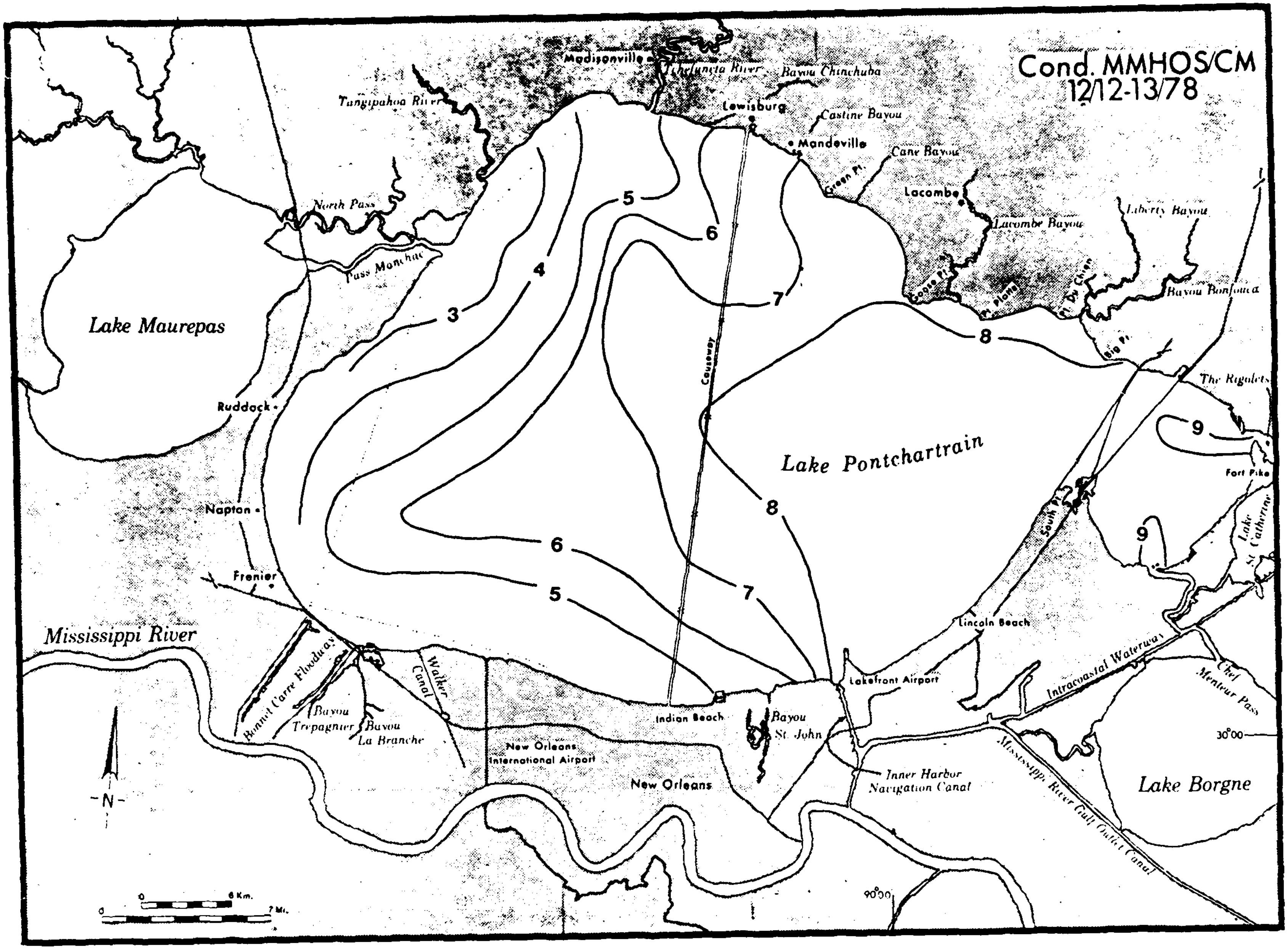


Figure A3-12. Surface conductivity map (mmhos/cm) of Lake Pontchartrain, LA, from cruises of December 12-13, 1978.

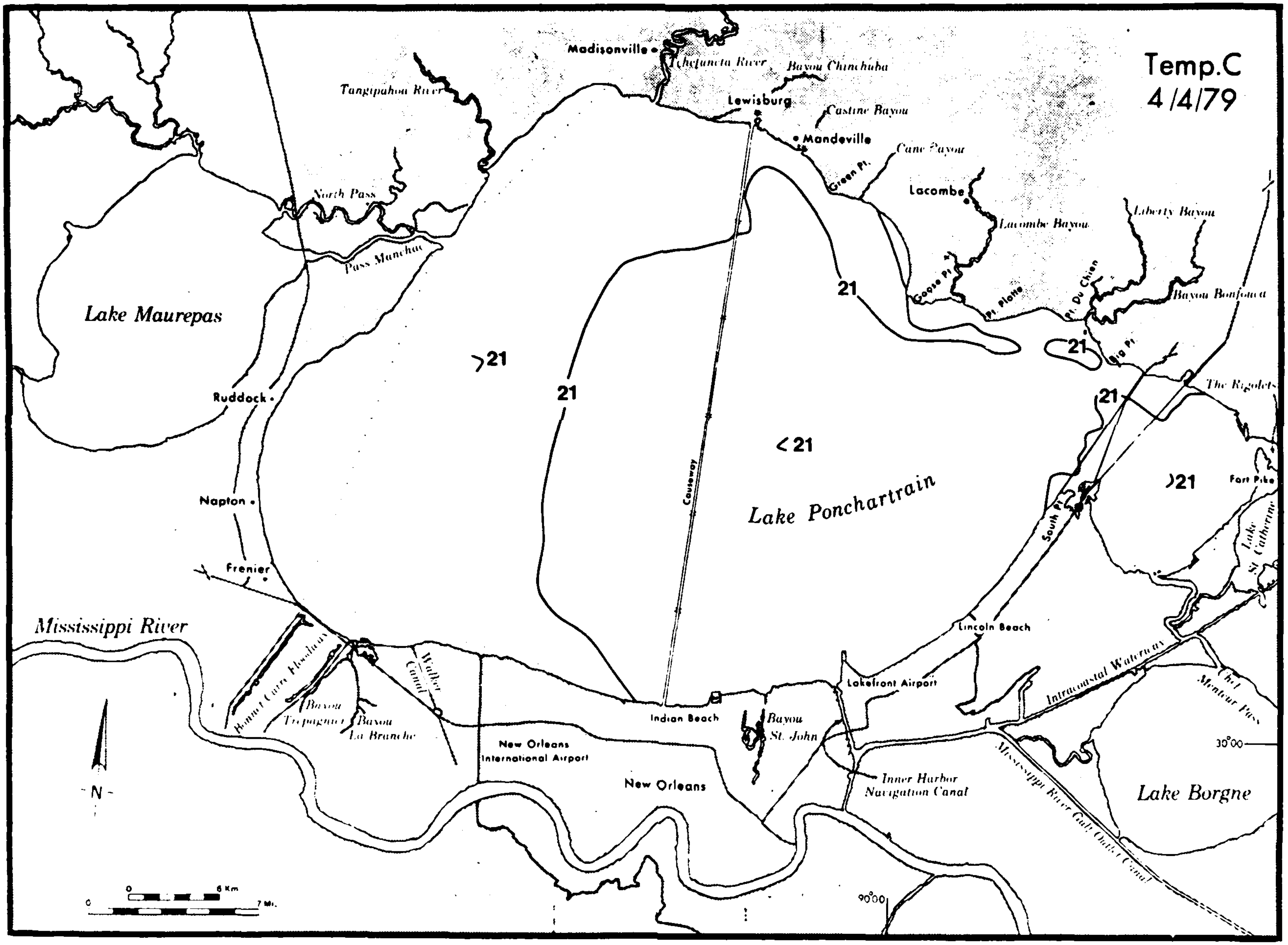


Figure A3-13. Surface temperature map (°C) of Lake Pontchartrain, LA from cruise of April 4, 1979.

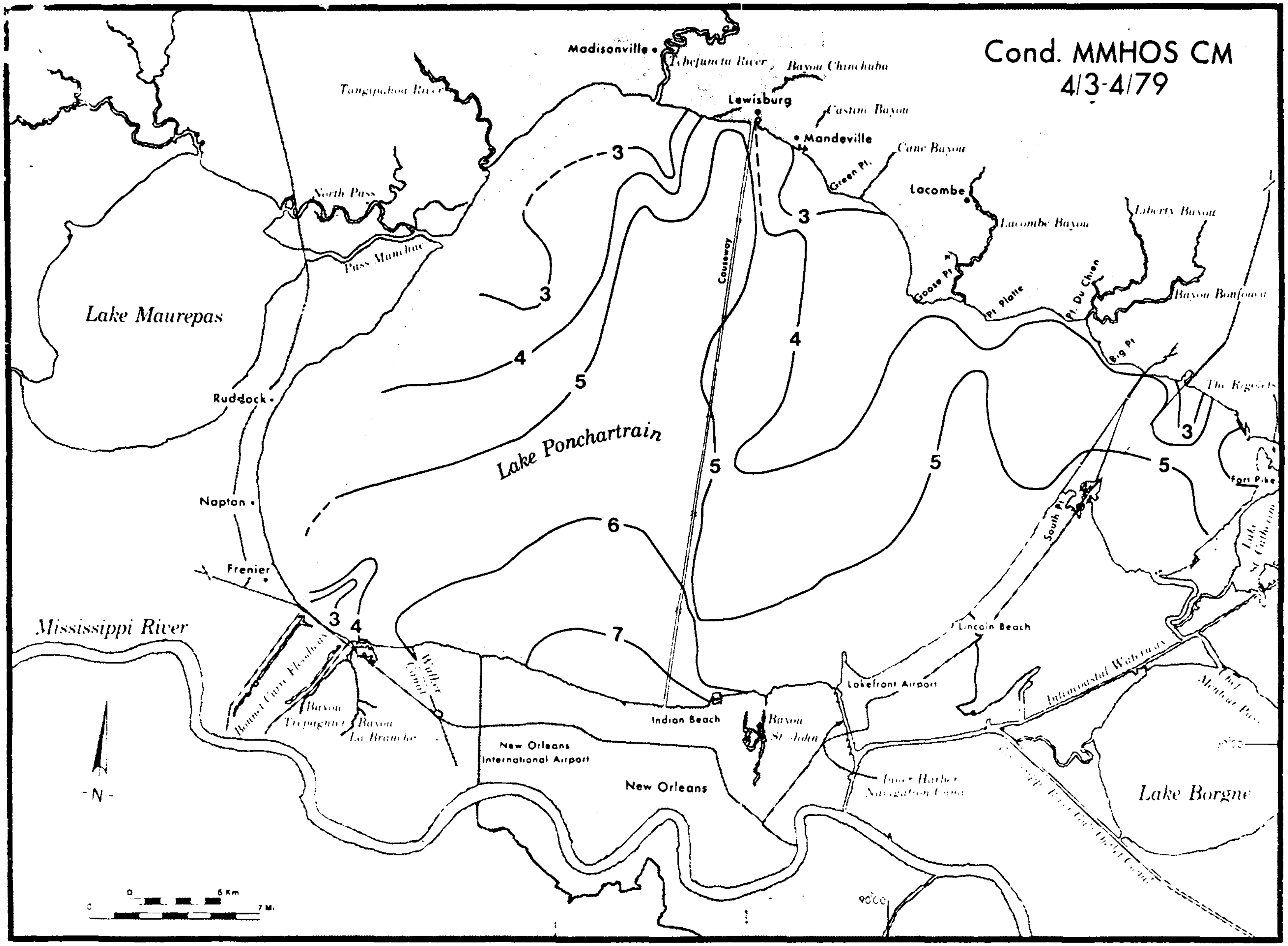


Figure A3-14. Surface conductivity map (mmhos/cm) of Lake Pontchartrain, LA, from cruise of April 4, 1979.

APPENDIX 4 - BONNET CARRE FLOODWAY STUDY MAPS

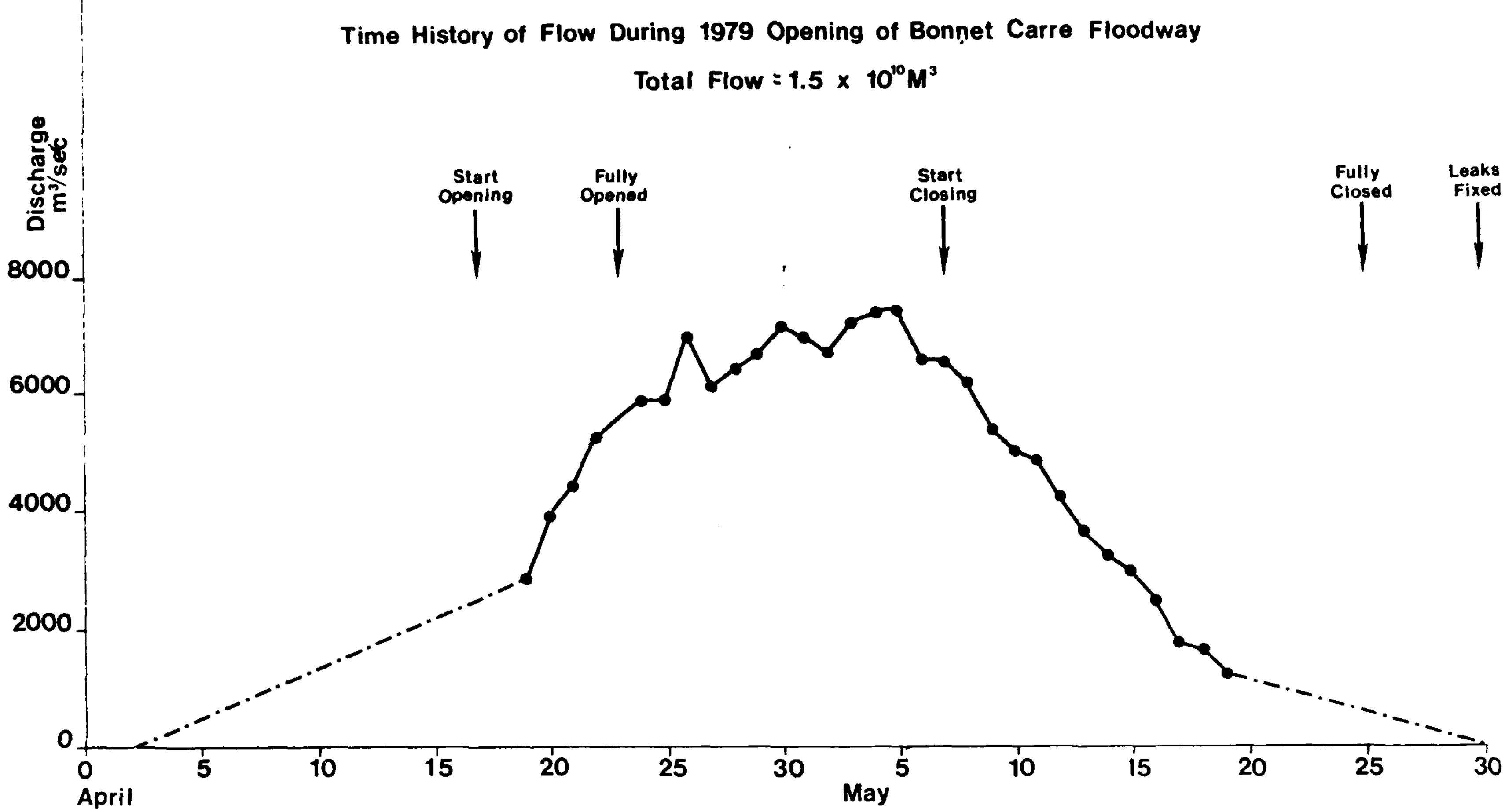


Figure A4-1. Time history of discharge (m^3/sec) from the April 1979 opening of the Bonnet Carre floodway. The total volume flow [illegible] period is indicated above the figure. Notes on operatic[illegible] floodway are also given (Data from U.S. Army Corps of Engine[illegible] 1979).

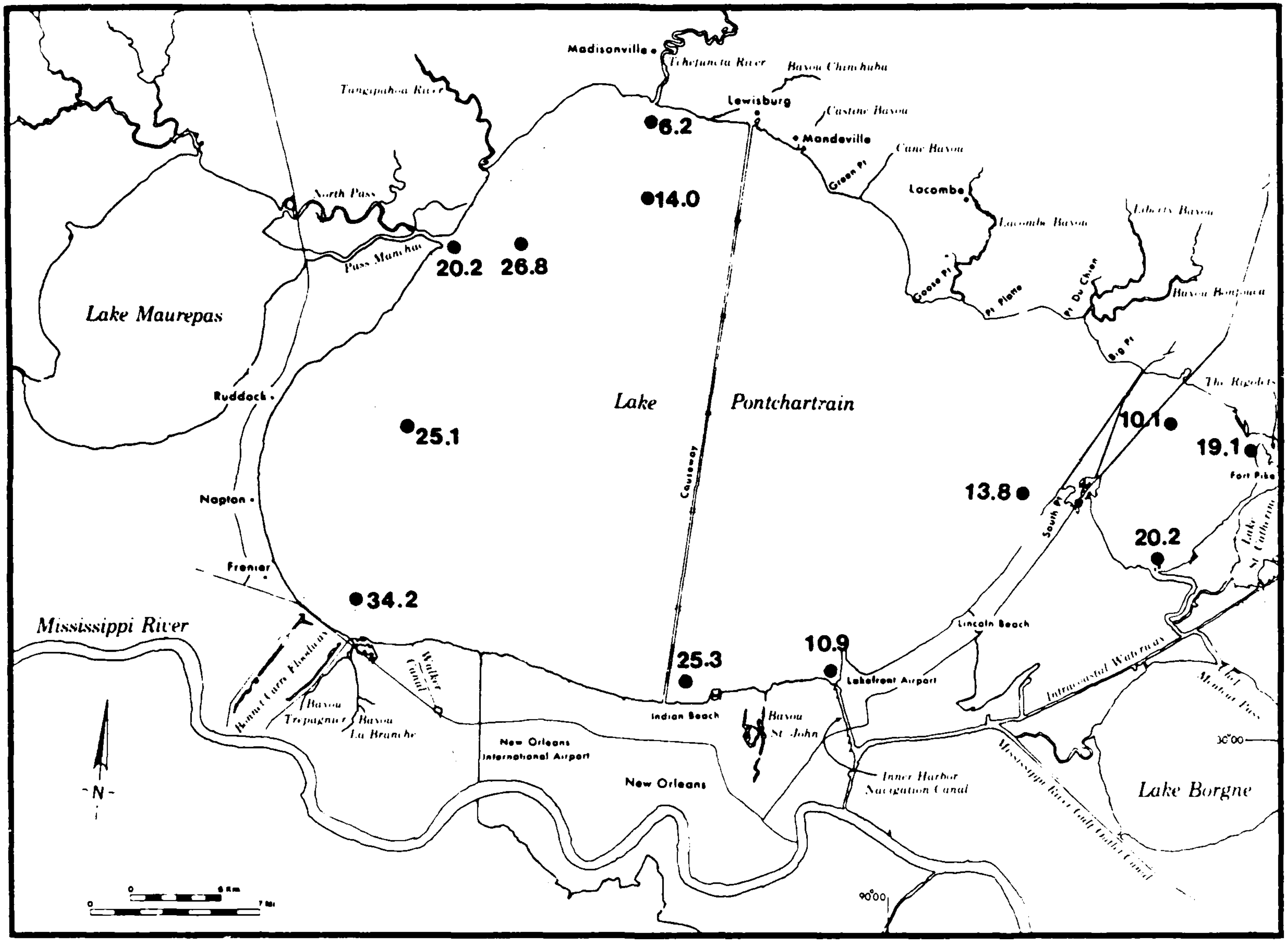


Figure A4-2. Map showing average suspended load concentrations (mg/l dry weight) in Lake Pontchartrain (Data from present study).

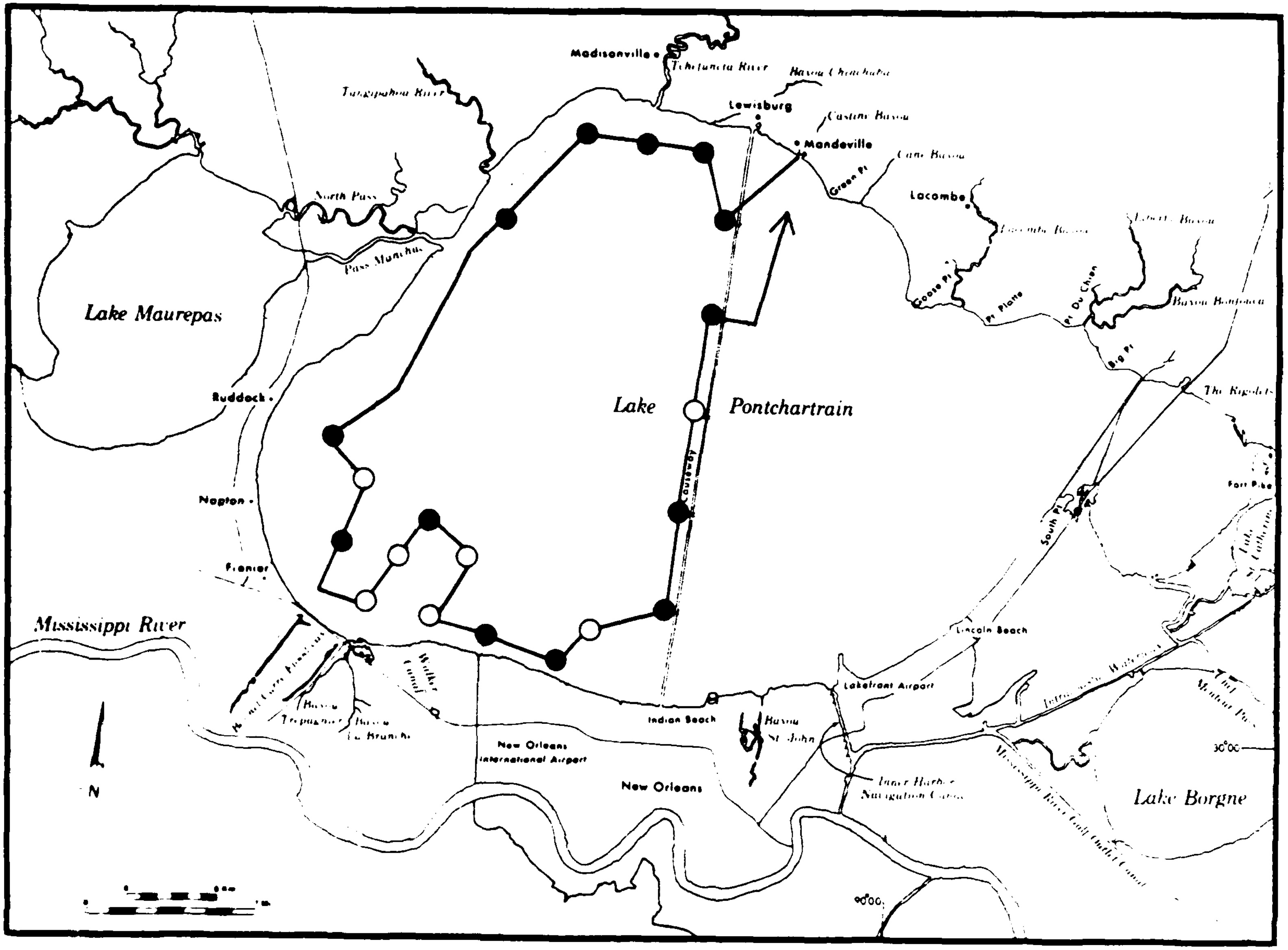


Figure A4-[illegible]. Cruise track for floodway study of April 26, 1979. Solid circles represent locations of suspended load samples collected while underway with a flow-thru system. Open circles represent anchor stations where triplicate samples were collected.

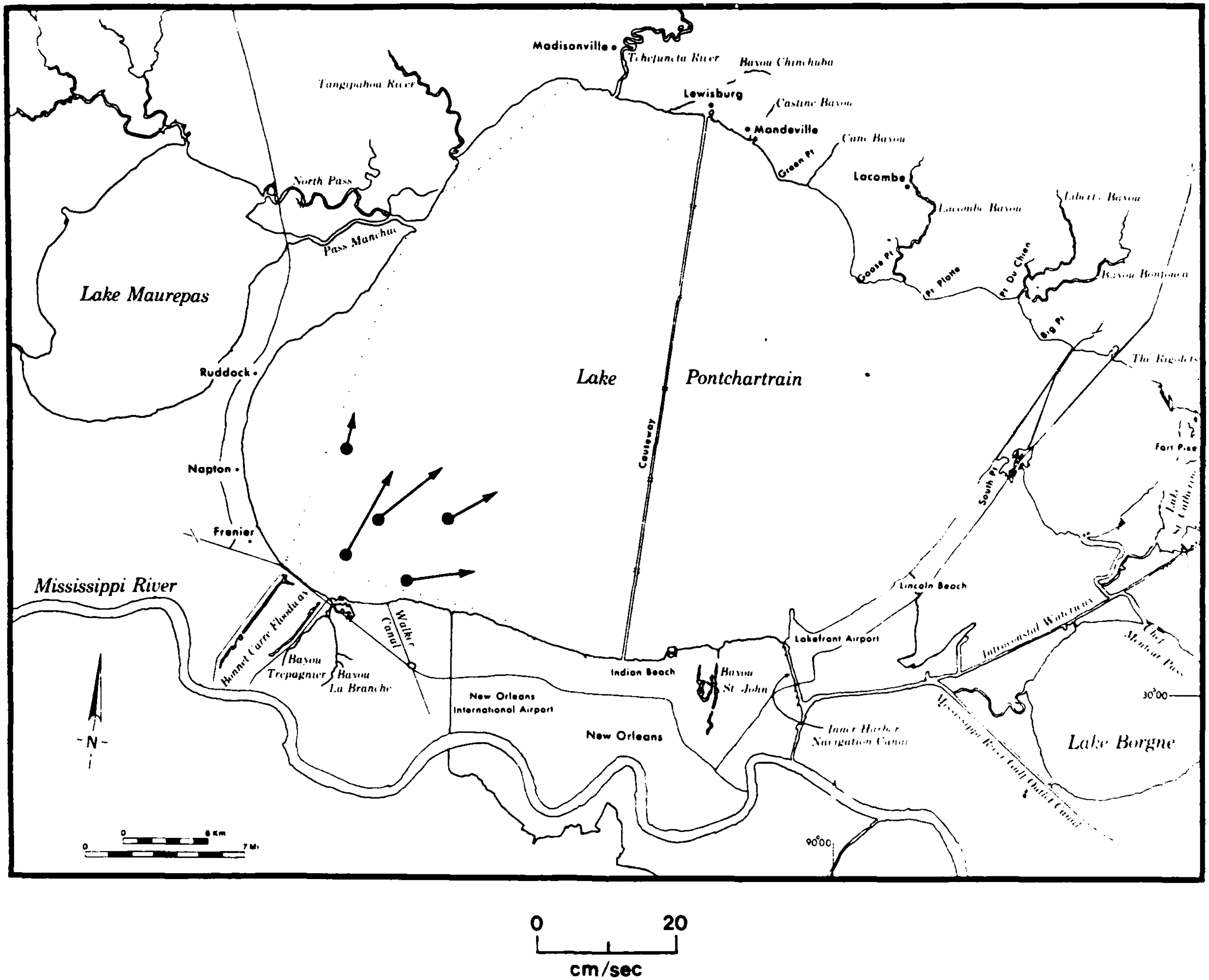


Figure A4-4. Map showing current vectors measured in Lake Pontchartrain, LA, on April 26, 1979. The scale is

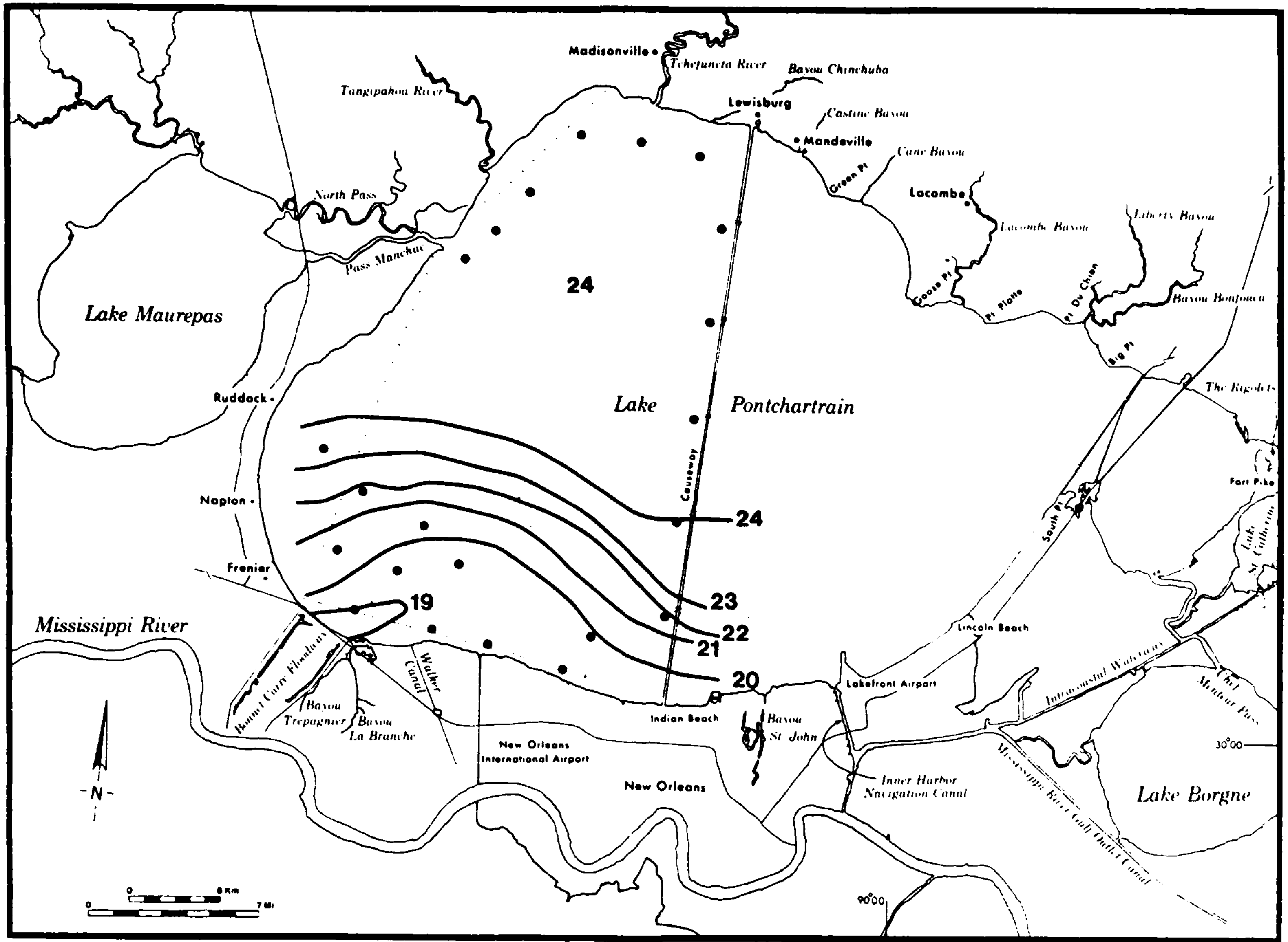


Figure A4-5. Surface temperature map (°C) of Lake Pontchartrain, LA, from cruise of April 26, 1979.

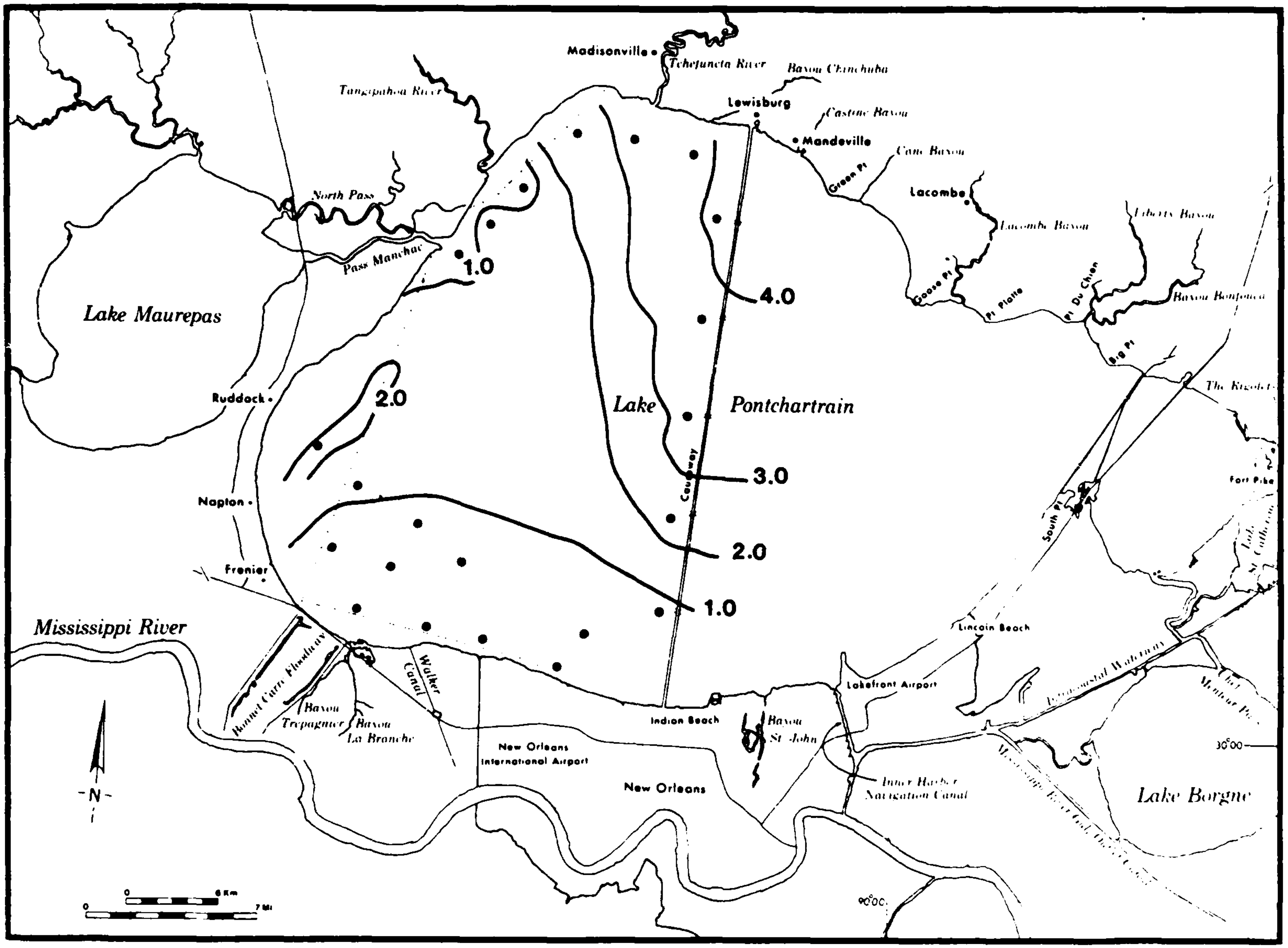


Figure A4-6. Surface conductivity map (mmhos/cm) of Lake Pontchartrain, LA, from cruise of April 26, 1979.

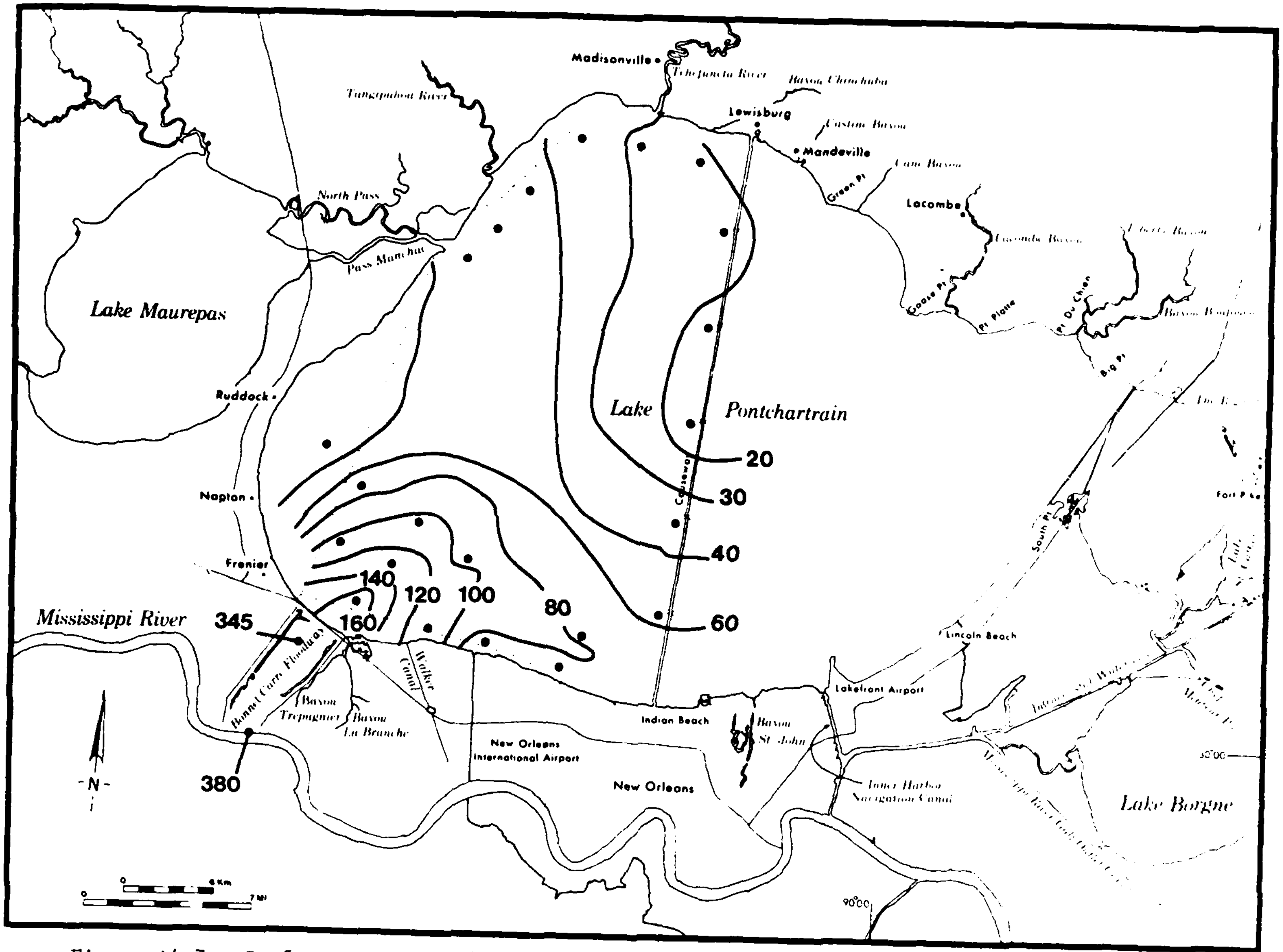


Figure A4-7. Surface suspended load map (mg/l dry weight) of Lake Pontchartrain, LA, from cruise of April 26, 1979. Dots indicate sample locations.

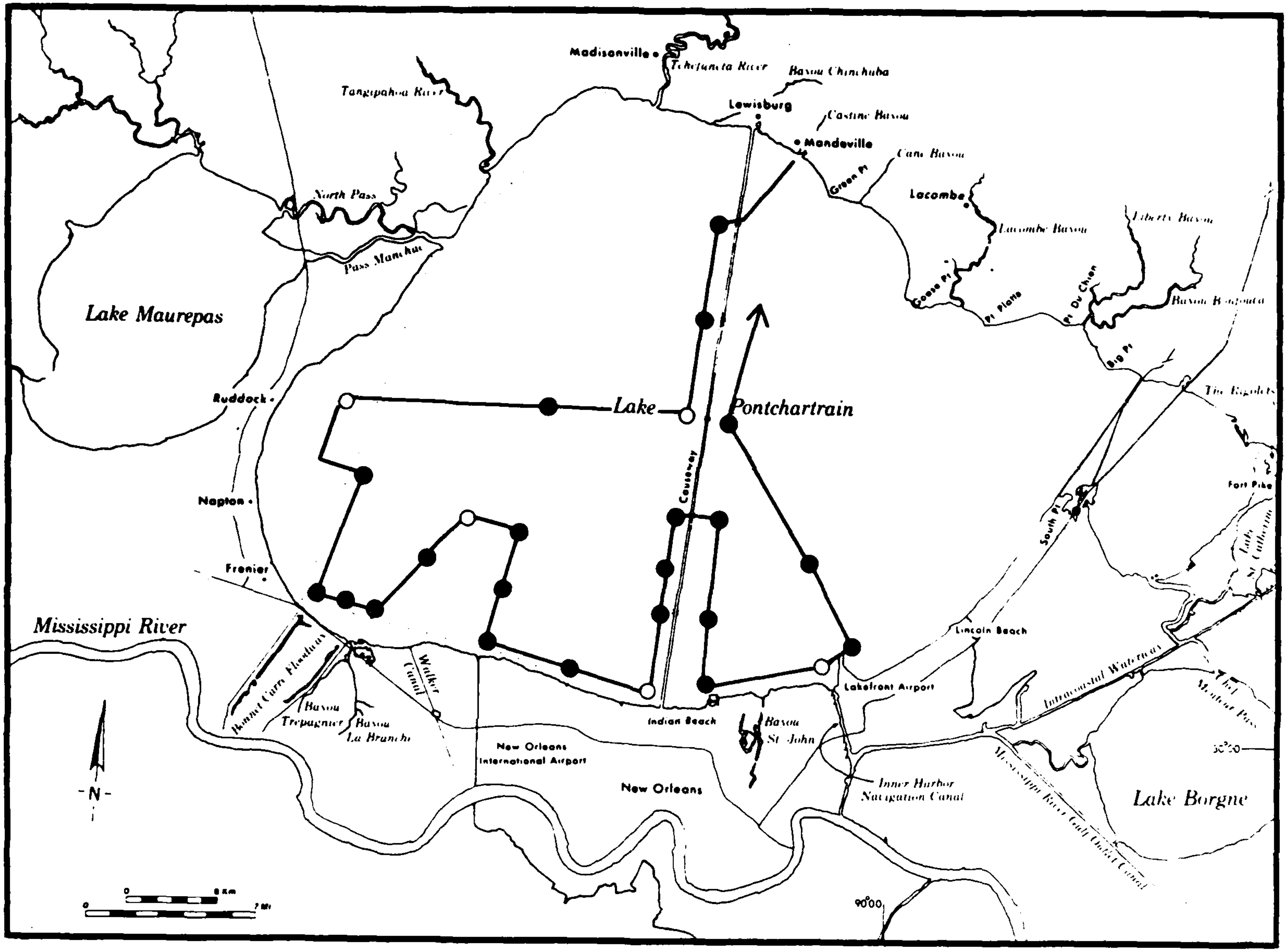


Figure A4-8. Cruise track for floodway study of May 9, 1979. Solid circles represent locations of suspended load samples collected while underway with a flow-thru system. Open circles represent anchor stations where triplicate samples were collected.

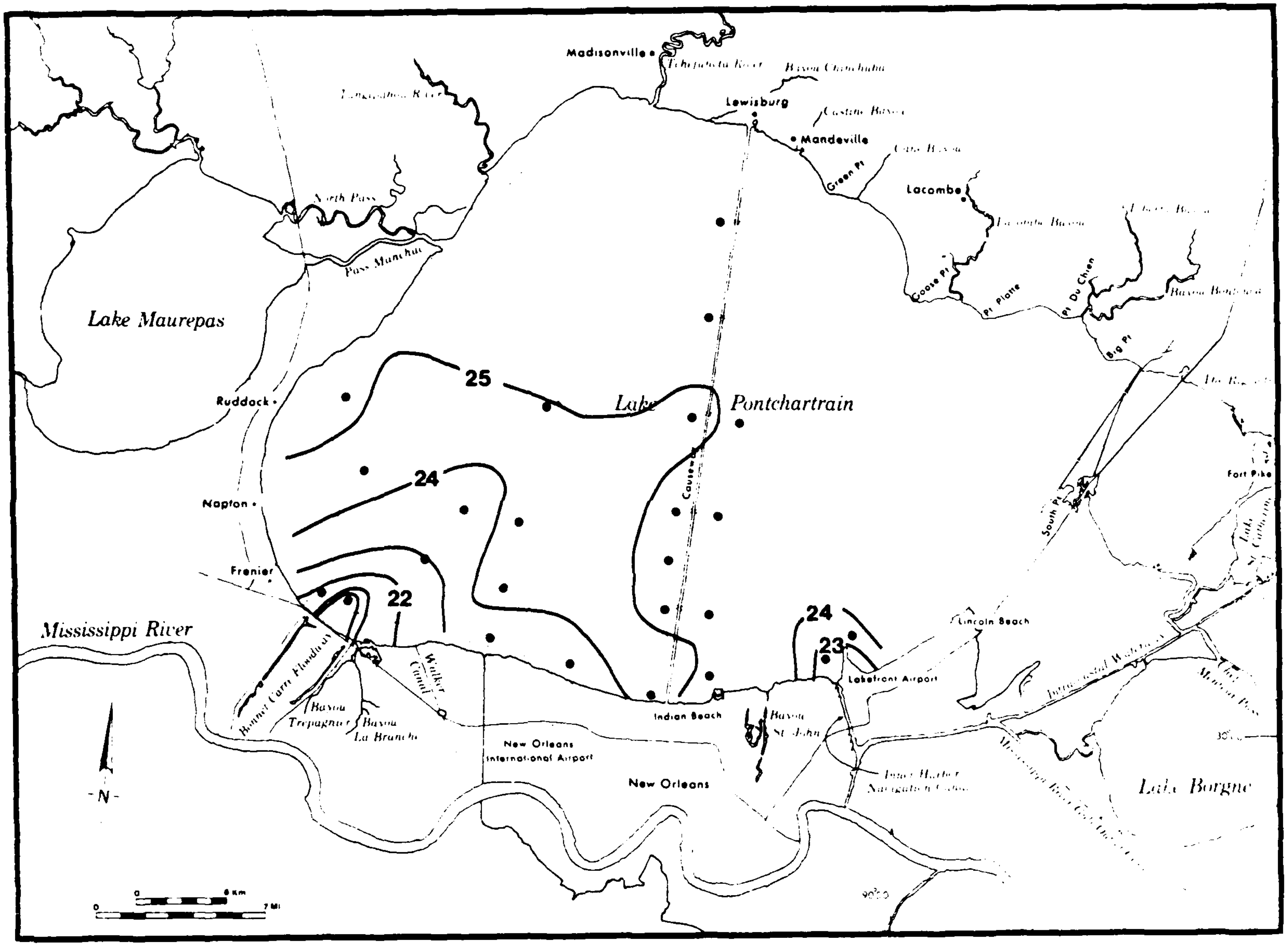


Figure A4-9. Surface temperature map (^{o}C) of Lake Pontchartrain, LA from cruise of May 9, 1979.

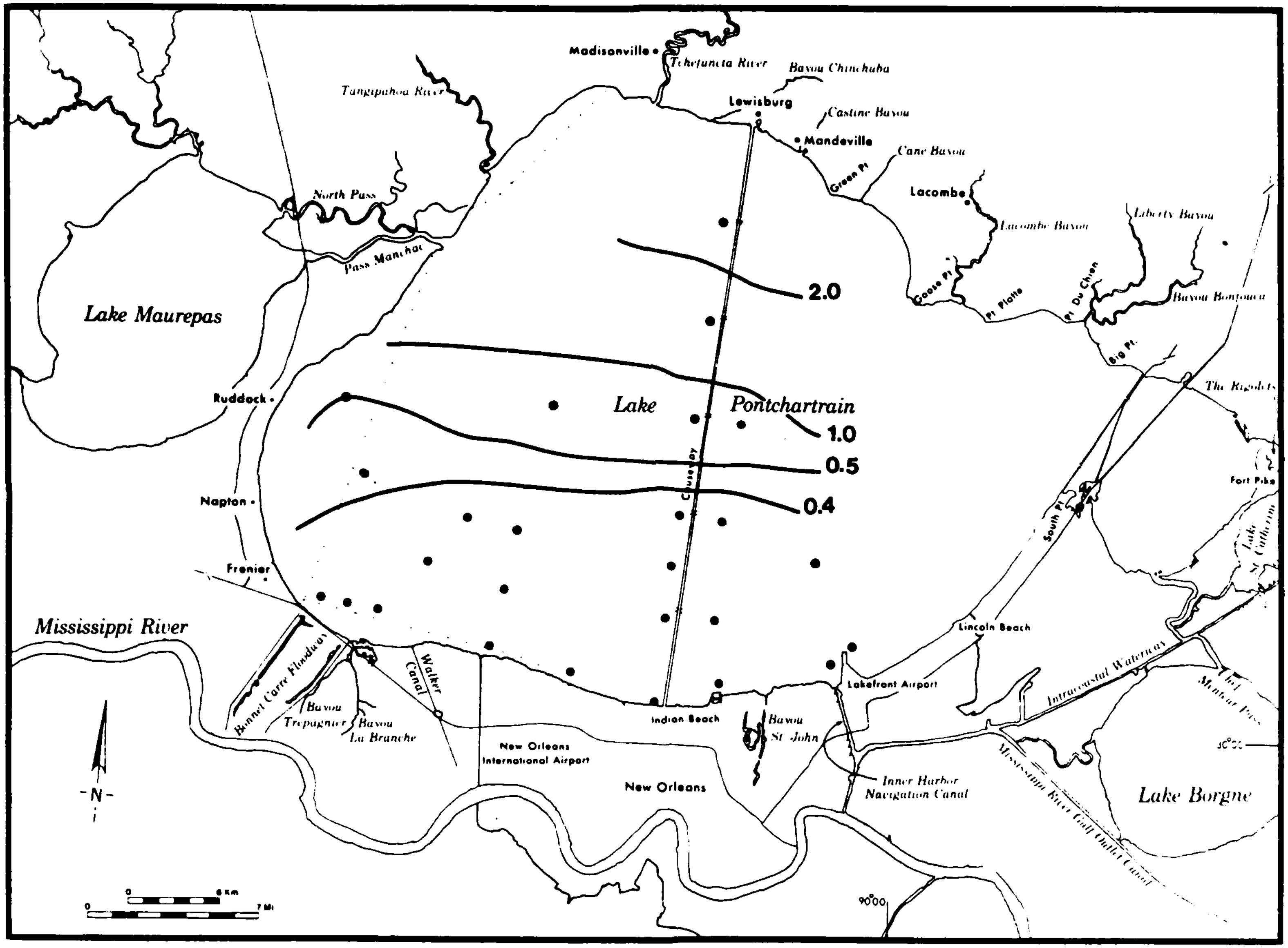


Figure A4-10. Surface conductivity map (mmhos/cm) of Lake Pontchartrain, LA, from cruise of May 9, 1979.

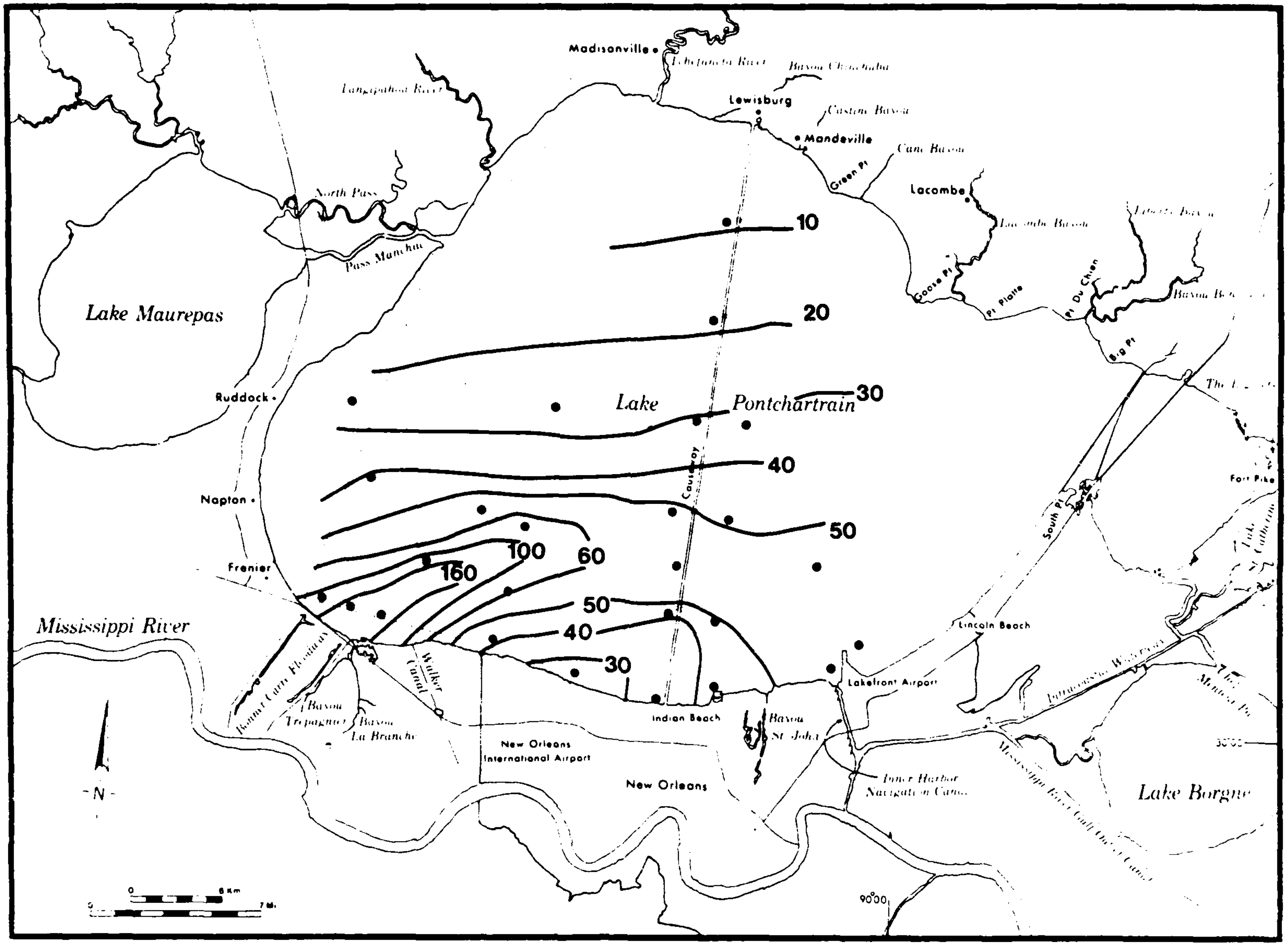


Figure A4-11. Surface suspended load map (mg/l dry weight) of Lake Pontchartrain, LA, from cruise of May 9, 1979. Dots indicate sample locations.

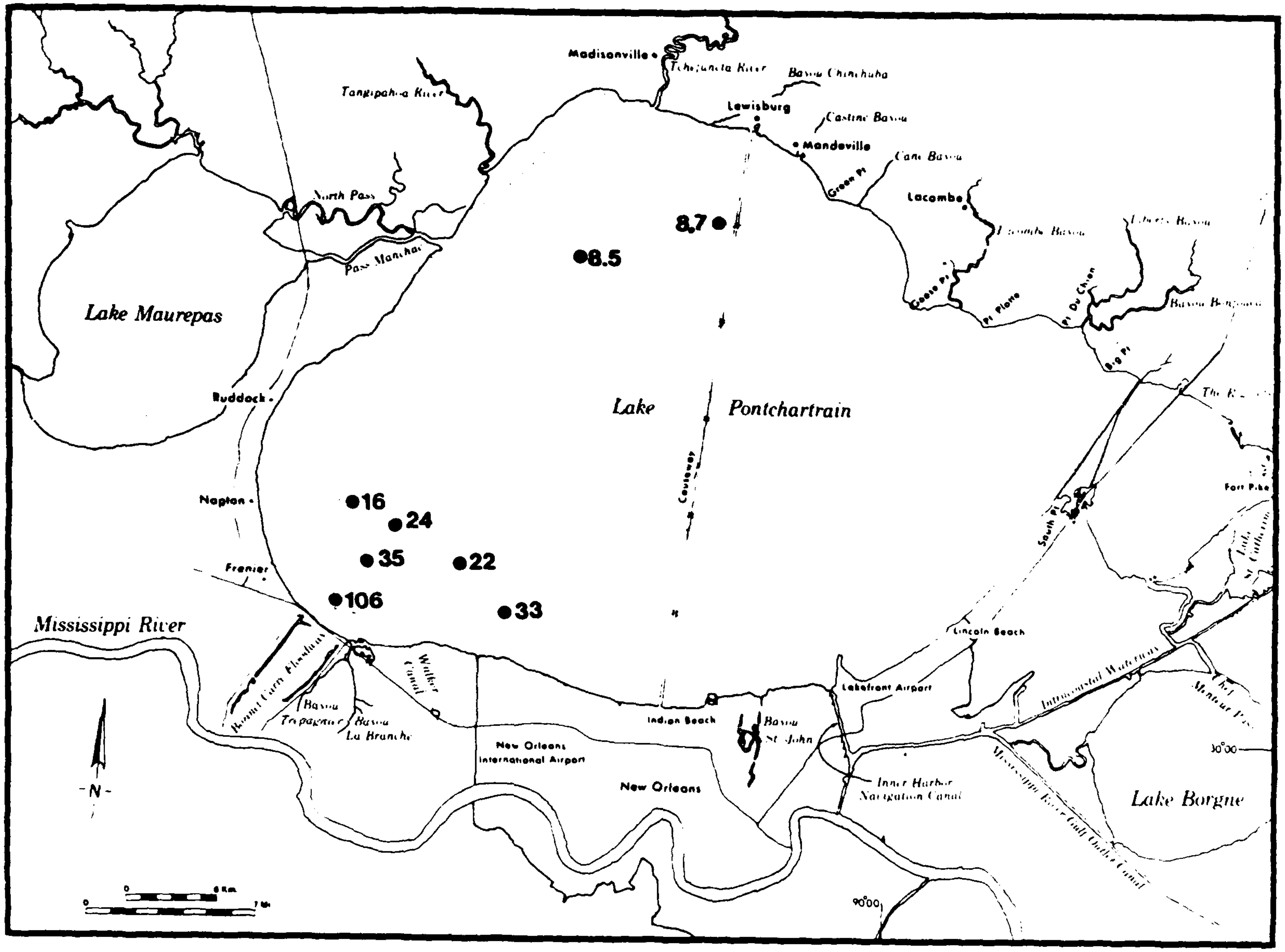


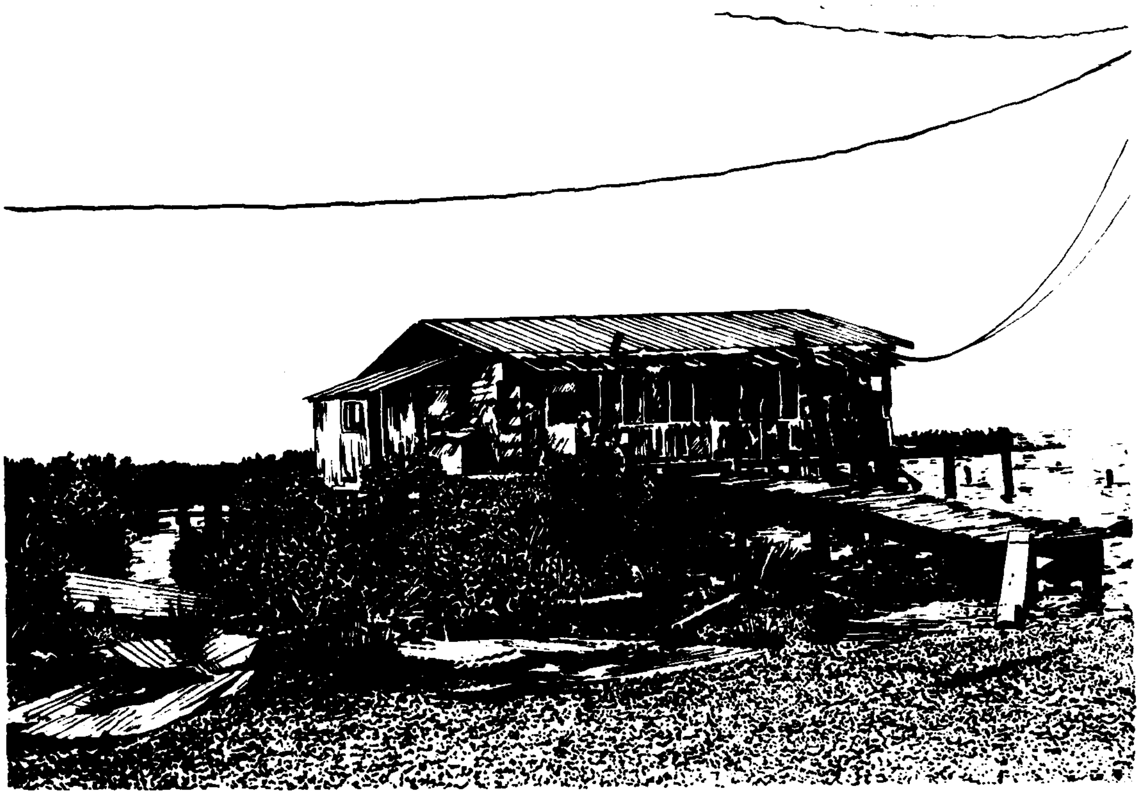
Figure A4-12. Surface suspended load map (mg/l dry weight) of Lake Pontchartrain, LA, from Benthos group cruise of May 15, 1979. Dots indicate sample locations.

APPENDIX 5 - CONDUCTIVITY AND SALINITY CONVERSION TABLE

Table A5-1. Conversion table giving salinity (ppt) as a function of conductivity (mmhos/cm) and temperature (°C)*

CONDUCTIVITY (mmhos/cm)	SALINITY IN PPT 0°	5°	10°	15°	20°	25°
1	1.0	--	--	--	--	.4
2	2.0	1.7	1.4	--	--	1.0
3	3.0	2.6	2.2	1.9	1.7	1.6
4	4.1	3.6	3.1	2.6	2.3	2.1
5	5.2	4.5	3.9	3.4	3.0	2.6
6	6.4	5.5	4.8	4.1	3.6	3.2
7	7.5	6.5	5.6	4.8	4.3	3.8
8	8.6	7.4	6.6	5.4	4.9	4.4
9	9.8	8.4	7.4	6.4	5.6	5.0
10	11.0	9.4	8.2	7.1	6.3	5.6
11	12.1	10.4	9.1	7.9	7.0	6.2
12	13.4	11.4	9.9	8.7	7.7	6.8
13	14.6	12.4	10.8	9.5	8.4	7.5
14	15.8	13.5	11.6	10.4	9.0	8.1
15	17.0	14.4	12.5	11.0	9.8	8.8
16	18.4	15.6	13.5	11.9	10.4	9.4
17	19.6	16.6	14.4	12.6	11.1	10.0
18	20.8	17.8	15.3	13.5	12.0	10.7
19	22.0	18.9	16.2	14.3	12.6	11.3
20	23.4	19.9	17.2	15.1	13.4	12.0

*Based on Nomograph produced by Beckman Instruments Inc., Cedar Grove New Jersey (Part No. L-227590).



Camp near Lacombe, Louisiana

Chapter 5

GENERAL HYDROGRAPHY OF THE TIDAL PASSES OF LAKE PONTCHARTRAIN, LOUISIANA

by

Erick M. Swenson

ABSTRACT

The general hydrography of the tidal passes of Lake Pontchartrain was studied on a number of cruises from May 1978 to February 1979. Time series of current speed and direction, conductivity, and temperature were measured.

Current data indicate mean flood current speeds of 50, 40, 40, and 33 cm/sec, corresponding to mean transports of 3750, 2000, 400, and 924 m^3/sec for The Rigolets, Chef Menteur Pass, Inner Harbor Navigation Canal (IHNC), and Pass Manchac, respectively. The ebb current speeds are 35, 45, 40, and 40 cm/sec, corresponding to transports of 2625, 2250, 400, and 1120 m^3/sec.

Salt budget calculations indicate that The Rigolets supplies about 40%; the Chef Menteur Pass supplies about 40%; and the IHNC, 20% of the total salt entering the lake.

An energy budget indicates that tides supply an average of 4.30×10^{12} ergs/sec to the lake. The majority ($\sim$90%) of this energy enters through The Rigolets.

Estimation of wind energy reveals that the tides predominate over wind at wind speeds less than 2 m/sec, winds and tides are about equal when wind speeds range between 2 to 3 m/sec, and winds predominate when they are greater than 3 m/sec.

Lake flushing time is estimated at 60 days under mean streamflow conditions.

INTRODUCTION

Lake Pontchartrain is connected to Lake Borgne by two natural tidal passes: The Rigolets and the Chef Menteur. A man-made tidal pass, the Inner Harbor Navigation Canal (IHNC), connects the lake to the Mississippi River Gulf Outlet (MRGO). A fourth pass, Pass Manchac, connects Lakes Pontchartrain and Maurepas.

The Rigolets Pass has a total length of 14.5 kilometers, an average depth of 8 meters, and a cross-sectional area at Lake Pontchartrain of 7500 m^2 (Fig. 1).

The Chef Menteur Pass has a total length of 11.3 kilometers, an average depth of 13 meters, and a cross-sectional area of Lake Pontchartrain of 2422 m^2 (Fig. 1).

The IHNC-MRGO system has a total length of 30 kilometers, an average depth of 7.5 m, and a cross-sectional area of 1125 m^2.

Pass Manchac has a total length of 15 km, an average depth of 8 m, and a cross-sectional area at Lake Pontchartrain of 2924 m^2 (Fig. 1).

These tidal passes play an important role in the dynamics of the Lake Pontchartrain system. The fresh water entering the lake from the various rivers must work its way across the lake to eventually exit through one of the passes. This water will carry with it various chemicals (e.g., salt, nutrients, sediments) and biological species. Similarly, any chemical or biological species that are to enter the lake from the ocean are also constrained to travel through these passes.

MATERIALS AND METHODS

From December 1977 to March 1979, a study was conducted to describe the general hydrography of Lake Pontchartrain (see Chapter 4). Details

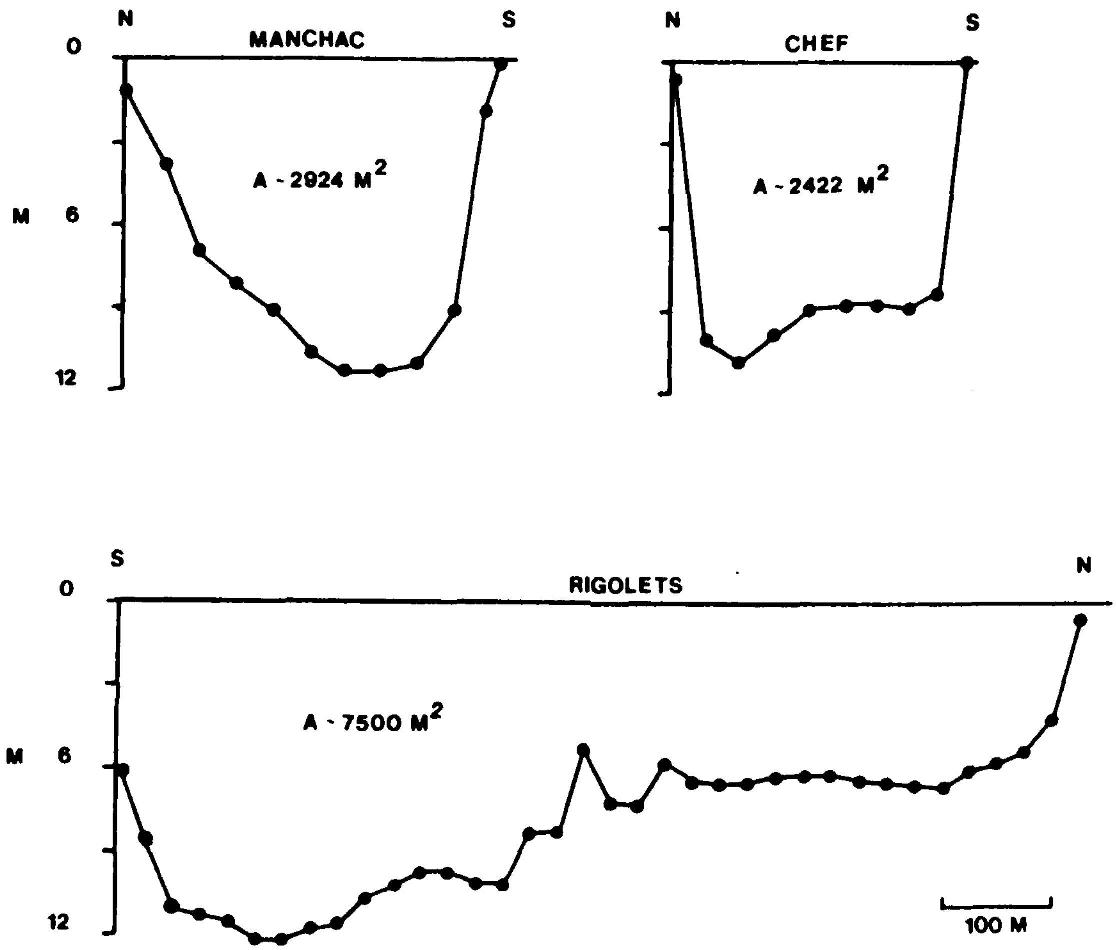


Figure 1. Cross sections at Lake Pontchartrain of Pass Manchac, Chef Menteur Pass, and The Rigolets. The total cross-sectional area (in m^2) is indicated on each section.

of the program were presented in a previous report by the present author. This report contains data concerning currents, tidal heights, salinity, and temperature collected in the tidal passes. Data from the present LSU study were used, along with records of tidal height, salinity, temperature, and streamflow obtained from the Geological Survey (USGS), the Corps of Engineers (COE), and the Waterways Experiment Station (WES). The main objective of this report is to describe the role the tidal passes play in the hydrodynamics of the lake system.

Data were collected during 24-hour sampling periods undertaken on a monthly basis in each of the three tidal passes. Current speed data came from two sources: 1) from current profiles collected at approximately one-hour intervals by the hydrography group using an Endeco type 110 current meter (the specifications are discussed in Chapter 4 of this report); and 2) from current speeds collected at surface, mid-depth, and bottom at approximately three hour intervals by the nekton and plankton groups using General Oceanics digital flow meters. (These meters have an accuracy of ±3% with a threshold of ∿10 cm/sec.)

Conductivity (salinity) and temperature data were collected simultaneously with the current speed data. The hydrography group used a Hydrolab Model 8000 conductivity-temperature-depth meter (the specifications are given in Chapter 4), and the nekton and plankton groups used a Yellow Springs Instrument Corp. salinity-temperature meter. (The accuracy of this instrument is ∿5% for salinity and ∿5% for temperature.) Like the general hydrography report (Chapter 4), all conductivities are referenced to 25°C (See Table 9 for conversion to salinity). The data base is summarized in Table 1.

Table 1. 24-Hour Data Summary for the Tidal Passes of Lake Pontchartrain, LA

Month	Area Sampled	Dates Sampled	Sampling Frequency
May 1977	The Rigolets[1]	5/1-2	every 3 hours
	Chef Menteur Pass[1]	5/2-3	every 3 hours
	IHNC[1]	5/5-6	every 3 hours
June 1977	The Rigolets[2]	6/5-6	every 1 hour
	Chef Menteur Pass[1]	6/7-8	every 3 hours
	IHNC[1]	6/8-9	every 3 hours
July 1977	The Rigolets[1]	7/10-11	every 3 hours
	Chef Menteur Pass[2]	7/11-12	every 1 hour
	IHNC[1]	7/12-13	every 3 hours
August 1977	The Rigolets[1]	8/7-8	every 3 hours
	Chef Menteur Pass[1]	8/9-10	every 3 hours
	IHNC[2]	8/10-11	every 1 hour
September 1977	The Rigolets[1]	9/5-6	every 3 hours
	Chef Menteur Pass[1]	9/6-7	every 3 hours
	IHNC[1]	9/7-8	every 3 hours
October 1977	The Rigolets[1]	10/3-4	every 3 hours
	Chef Menteur Pass[1]	10/4-5	every 3 hours
	IHNC[2]	10/5-6	every 1 hour
November 1977	The Rigolets[1]	11/6-7	every 3 hours
	Chef Menteur Pass[1]	11/8-9	every 3 hours
December 1977	The Rigolets[2]	12/4-5	every 1 hour
	Chef Menteur Pass[1]	12/5-6	every 3 hours
	IHNC[2]	12/7-8	every 1 hour
January 1978	The Rigolets[1]	1/8-9	every 3 hours
	Chef Menteur Pass[1]	1/9-10	every 3 hours
	IHNC[1]	1/10-11	every 3 hours
February 1978	The Rigolets[1]	2/5-6	every 3 hours
	Chef Menteur Pass[1]	2/6-7	every 3 hours
	IHNC[1]	2/8-9	every 3 hours

[1]Data from plankton group.

[2]Data from hydrography group.

Range Locations: The Rigolets--one station on south shore near Hwy. 90 Bridge.
Chef Menteur Pass--one station on south shore near Hwy. 90 Bridge.
IHNC--one station on east shore at harbor police dock.

RESULTS

Appendix 1 presents examples of vertical profiles of current speeds and directions, conductivity, and temperature. In The Rigolets, the Chef Menteur Pass, and Pass Manchac, the vertical structures of currents are quite similar. The current profiles show a decrease in speed from surface to near bottom ($\sim$ one meter off of bottom) in conjunction with an essentially constant current direction. Variation in direction with depth is usually less than 20 degrees (° magnetic). The temperature profiles show a slight decrease in temperature with depth, normally less than 1°C. Conductivity increases with depth and the increase is at most 2 mmhos/cm. This type of profile, which is fairly homogeneous in the vertical, indicates that there is not normally a two-layer system in these three passes.

The IHNC (Appendix 1, Fig. A1-5 and A1-6) does show evidence of a two-layer system. The temperature and conductivity profiles (Fig. A1-5) show a fairly uniform water mass from the surface to about 2 meters depth, followed by a sharp increase in conductivity (and decrease in temperature) from 2 meters to the bottom.

Appendix 2 presents time series plots of current speed and direction, conductivity, and temperature for each of the passes. All directions are those towards which the currents are flowing. In most cases, the plots represent vertical averages of the parameters. When there was a significant difference in the vertical, both surface and near bottom ($\sim$ 1 m off of bottom) values are given.

DISCUSSION AND IMPLICATIONS

I. Currents, Salinity, and Temperature Patterns

Both The Rigolets and the Chef Menteur Pass show little variation in physical parameters from top to bottom. These types of profiles are indicative of well-mixed water masses travelling through the tidal passes.

In a system where the ratio of width to depth is small and river flow is large (such as the Mississippi Delta), one would expect a two-layer system with salt water entering along the bottom and fresh water exiting at the surface (Dyer 1973). The conditions in The Rigolets and the Chef Menteur Pass are such that the ratio of width to depth in these passes is relatively large and the tidal flow is much larger than the streamflow; thus, one would not expect such a two-layer flow to occur. In addition, the conductivity gradient between the water in Lake Pontchartrain and the water that enters through these passes is not too great. Consequently, there is no highly saline "ocean" water to travel along the bottom.

Because these two passes have an essentially homogeneous water mass, the chemicals and biological species (plankton) entering (or leaving) the lake essentially can travel at any level in the water column. The plankton data collected as part of this study indicate that a majority of the macroplankton travel at approximately mid and near bottom depths (Fannaly, Chapter 15). This indicates that although these two passes appear to be physically homogeneous, they are not biologically homogeneous.

The IHNC, however, does show definite evidence of a "salt wedge," which moves up the pass on a flooding tide. This feature is most noticeable on the time series plots (Appendix 2, Fig. A2-4 and A2-5) and probably arises because the canal is connected to the Gulf. The connection allows the more highly saline (much more saline than Lake Borgne) and hence more dense gulf water to work its way along the bottom of the pass towards the lake. This type of current pattern is probably quite favorable to oceanic (gulf) organisms and allows them to travel along the bottom of the canal and into the Lake Pontchartrain system; a view also expressed by Darnell (1979). It is probable that various chemicals (e.g., salt and nutrients) are also able to enter the lake from the gulf.

The time series curves (Appendix 2) show some general features. The diurnal tidal cycle of $\sim$25 hours is evident on the plots, particularly if one looks at the direction time series. There are events (Fig. A2-4) when one part of the tide may be extended due to wind effects. For example, an easterly wind could force water into the lake and cause it to override the ebb tide, thus extending the flood tide.

The temperature does not show any particular relationship to the tide because the passes connect two systems between which there is little temperature differential.

The conductivity data do, in general, show a relation to the tidal signal. On a flooding tide, the conductivity increases; on an ebbing tide, it decreases. There is one notable exception in The Rigolets (Appendix 3, Fig. A2-1), where the conductivity decreased during the flood. This probably represents a situation where fresh water from the Pearl River was entering the pass during the flooding tide.

The current data collected in the passes are summarized in Table 2, which gives the minimum, maximum, and mean flood and ebb current speeds (vertical averages) for each of the passes. The corresponding transports (based on the cross-sectional areas shown in Figure 1) are also given.

The speeds measured for the three tidal passes are based on data collected by both the hydrography group and the plankton group during monthly 24-hr anchor studies at one location in the pass (see Table 1). Thus, the data in Table 1 are limited because they only cover a total of about 12 tidal cycles. To have a more accurate picture of the tidal flow, one would need continuous data over a period of at least a month to account for diurnal inequalities. Such data were unavailable. The transport data have been calculated by multiplying the channel cross-sectional area by the vertically averaged current speed (samples were made at three depths: surface, mid-depth, and near bottom). The assumption has been made, therefore, that the flow is uniform across the channel. This assumption introduces an error into the transport estimates and hence into subsequent water budget calculations. Sanford (1977) indicated that errors of about 20% may result by making such an assumption.

Thus, the results presented in this report should be considered as first approximations of the volume flows and hence of the water budget for the Lake Pontchartrain system.

II. Flushing Times

A. General Considerations

The flushing time of an estuary is defined as "the time required to replace the existing fresh water in the estuary at a rate equal to the river discharge" (Dyer 1973). Thus, flushing is calculated:

Table 2. Current Statistics for Passes in Lake Pontchartrain, LA, During 1978

		FLOOD			EBB		
		MIN	MAX	MEAN	MIN	MAX	MEAN
THE RIGOLETS	Speed (cm/sec)	7.0	90.0	50.0	7.0	70.0	35.0
	Transport (M^3/sec)	525	6750	3750	525	5250	2625
CHEF MENTEUR PASS	Speed (cm/sec)	7.0	120.0	40.0	7.0	90.0	45.0
	Transport (M^3/sec)	350	6000	2000	350	4500	2250
INNER HARBOR NAVIGATION CANAL	Speed (cm/sec)	3	70	40	3	55	40
	Transport (M^3/sec)	30	700	400	30	550	400
MANCHAC	Speed (cm/sec)	6.0	62.0	33	8.0	59.0	40
	Transport (M^3/sec)	168	1736	924	224	1652	1120

$$t = Q/R$$

where:

t = flushing time

Q = amount of river water in the estuary

R = river flow

Two methods for calculating the flushing time are: 1) the fraction of fresh water method; and 2) the tidal prism method (Dyer 1973).

B. Fraction of Fresh Water Method

In this method, the amount or fraction of fresh water in the estuary is calculated, based upon salinities, using the following relation:

$$f = \frac{S_s - S_n}{S_s}$$

where:

f = mean fraction of fresh water concentration

S_s = salinity of "seawater" entering the system

S_n = mean salinity in the system.

The total volume of fresh water (Q) is then found by multiplying f by the volume of the segment. The flushing time is calculated by dividing Q by the river flow.

C. Tidal Prism Method

In this method, the water entering the system on the flood tide is assumed to be completely mixed with the water inside. The amount of river water plus the tidal flow is assumed to equal the tidal prism. On the ebb, this volume of water is removed and the fresh water content of it is equal to the river water added. Essentially this method has assumed complete tidal mixing.

The flushing time (in tidal cycles) is calculated by:

$$t = \frac{V_L + P}{P}$$

where:

t = flushing time

V_L = low tide volume

P = tidal prism.

D. Calculation for Lake Pontchartrain

The flushing time for Lake Pontchartrain has been calculated using each of the above-mentioned methods. The results are presented in Table 3.

E. Discussion

In comparing the flushing times, it can be seen that the estimates give a range of 20 to 105 days. The 20 day estimate has assumed that with each tidal cycle, a volume of water equal to the tidal prism has been replaced. This assumption of complete mixing may not be valid for Lake Pontchartrain. The water at the far west (end) of the lake (or any estuary) may not reach the outflow point, and some of the water that leaves on the ebb may return on the next flood (Officer 1976). Thus this method can give an exaggerated estimate of the flushing rate (Dyer 1973). The other method attempts to solve the problem by using salinity ratios to account for the mixing.

The flushing time estimated is only a rough approximation. The formulas used are primarily for estuaries with unrestricted access to the open sea. A better estimate of the flushing time could be obtained by using a dispersion model at the lake, thus taking into account the residence times and dispersion coefficients of salt, to predict salinity

Table 3. Calculation of Flushing Times for Lake Pontchartrain, LA, During 1978.

A) fraction of fresh water

$$f = \frac{Ss - Sn}{S_S} = \frac{3.5‰ - 2.3‰}{3.5‰} = .343$$

$$Q = (f)\ (V) = (.343)(6.64 \times 10^9 m^3) = 2.28 \times 10^9 m^3$$

$$t = Q/R = (2.28 \times 10^9 m^3)/(250\ m^3/sec)$$

$$= 9.12 \times 10^6\ sec \sim 105\ days$$

B) tidal prism

$$t \quad \frac{V_{L+P}}{P} \quad \frac{(6.30 \times 10^9 m^3) + (3.25 \times 10^8 m^3)}{3.25 \times 10^8 m^3}$$

$$= 20\ cycles = 20\ days$$

Data Used in Calculation**

$A =$	$1.66 \times 10^9\ m^2$	area of lake
$V =$	$6.64 \times 10^9\ m^3$	volume of lake
$V_L =$	$6.32 \times 10^9\ m^3$	low tide volume
$P =$	$3.25 \times 10^8\ m^3$	tidal prism volume
$\overline{R} =$	$250\ m^3/sec$	mean riverflow
$\overline{Sn} =$	2.3‰	mean lake salinity
$Ss =$	3.5‰	mean salinity of Lake Borgne (Gagliano et al. 1970)

*The methods were used (i.e., A, B, and C), as indicated in text.

**Data were collected as part of the present study.

concentrations over the entire lake. From this model, one could predict flushing times for various sections of the lake. It is probable that the far (west) end of the lake has a longer flushing time than the east end, which is closer to the tidal passes. A dispersion model could account for these differences. At present, such a model does not exist for the lake. We can conclude, however, that a reasonable estimate would be about 60 days. This estimate would apply to mean streamflow conditions. During high inflow periods (spring), the flushing rate would probably be increased. Indeed, the floodway data (Chapter 4) show that the lake returned to normal (or pre-floodway opening) conditions in about a month, indicating a flushing time of about 30 days under high inflow conditions. Similarly, under low inflow conditions (summer), the flushing time could increase.

III. Water Budget

Using data on streamflow from the USGS stations for five rivers entering the lake (Tickfaw, Amite, Comite, Tchefuncte, and Tangipahoa), seasonal inputs of fresh water were determined. The USGS data give flows upstream from the lake. In order to obtain the volume entering the lake, flow data collected at the river mouths by the COE (1962) were used in conjunction with USGS records to determine a scale factor by which the gage data can be multiplied to get the flow into the lake. Table 4 presents the results. The average scale factor of 2.4 was used in all the water budget calculations.

In order to estimate runoff from areas where there are no gages, rainfall data (from National Oceanic and Atmospheric Administration [NOAA]) were used in conjunction with drainage basin size. Figure 2

Table 4. Scale Factor[1] for Rivers Entering Lake Pontchartrain, LA, During 1978

Month	Tchefuncte	Tangipahoa	Amite	Tickfaw
October	1.4	1.2	1.7	1.4
November	1.1	1.1	1.1	1.2
December	1.3	1.0	1.1	1.2
January	2.1	1.0	1.1	1.2
February	4.2	1.3	1.8	2.9
March	5.3	1.5	2.1	3.2
April	4.9	1.3	1.7	2.4
May	4.4	1.3	1.7	2.4
June	5.1	1.5	2.0	3.5
July	4.5	1.3	1.6	3.1
August	5.1	1.4	1.9	3.3
September	4.9	1.4	1.9	3.1
Average correction factor		2.4		

[1] Correction Factor = $\frac{\text{Flow into Pontchartrain}}{\text{Flow at Gage}}$

- Flow into Lake Pontchartrain from Army Corps of Engineers (1962).

- Flow at gage from U.S.G.S. records.

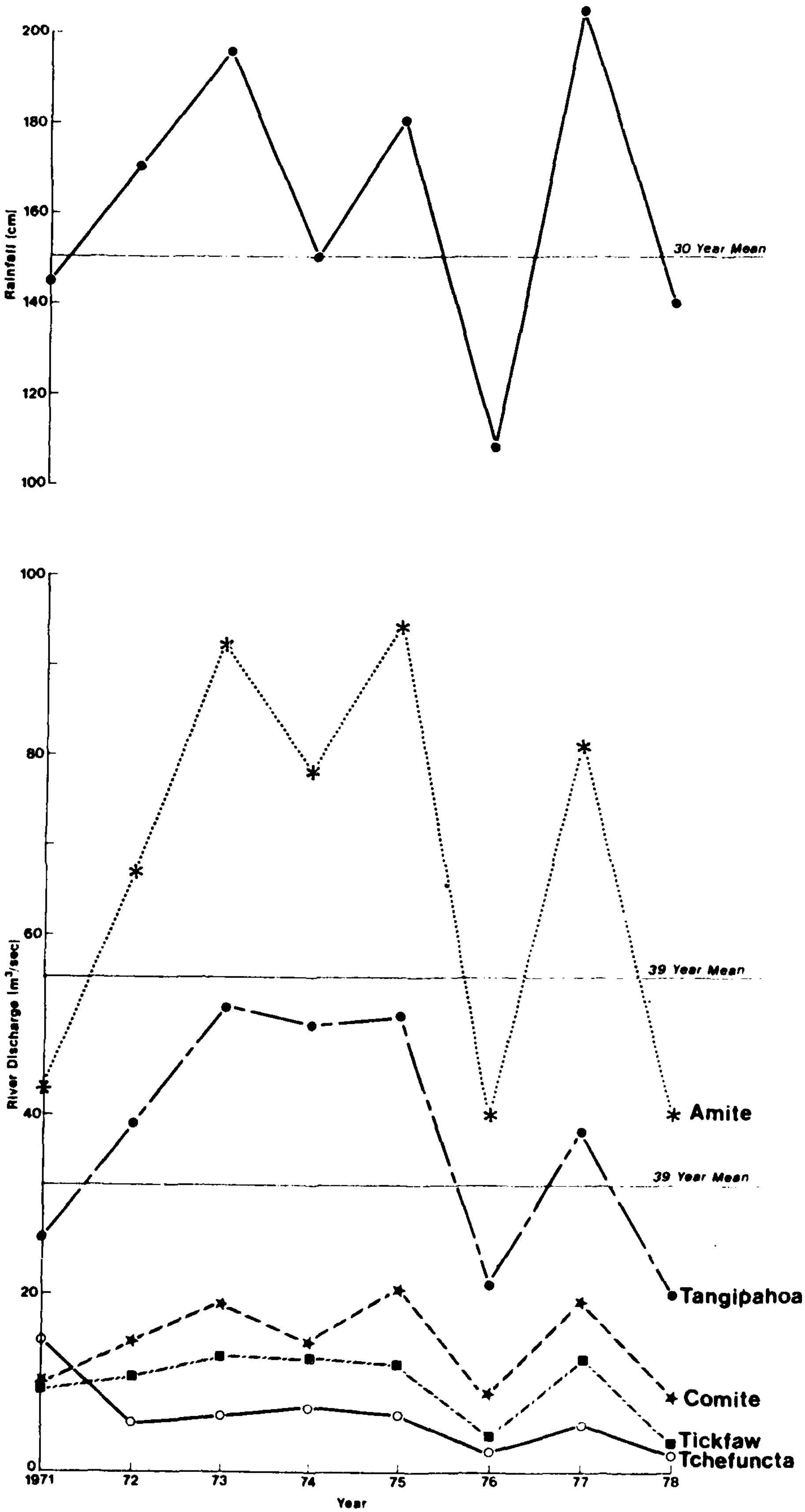


Figure 2. Time series plots of yearly values of rainfall in cm (top), and river discharge (m^3/sec) for five rivers entering Lake Pontchartrain, LA, for 1971 through 1978.

shows a plot of rainfall and streamflow for the five rivers. It is evident that the rivers are highly correlated with the rainfall. A regression between river flow and rainfall (on a monthly basis) for the Tangipahoa River is shown in Figure 3. This regression equation was scaled by the drainage basin area to give flow per unit area of basin surface:

$$Q = [5.1 \times 10^{-4} R + 5.7 \times 10^{-3}] AS$$

where:

Q = mean river flow (discharge) in m^3/sec

R = monthly rainfall in cm

A = drainage area of basin in square km

S = scale factor (~ 2.4).

I have assumed that this relationship would hold for all of the rivers and bayous in the Pontchartrain Basin because there is an excellent relationship between streamflow and basin size, as indicated in Figure 4.

Water inputs and outputs through the tidal passes were computed based upon the average flood and ebb tide flows given in Table 2. The tidal speeds were multiplied by the channel cross-sectional area (Fig. 1) to get the volume flow through the channel.

The streamflow and tidal flow data were combined to give a rough estimate of the seasonal water budget for the lake. The results are presented in Table 5. The long-term average streamflows (from USGS records) are given, along with the 1978 flows (calculated as discussed above), on a seasonal basis. Note that there are no "long-term" tidal pass flows, because these data do not exist. Table 5 also lists the percent contribution of each item. To "test" the input figures, the

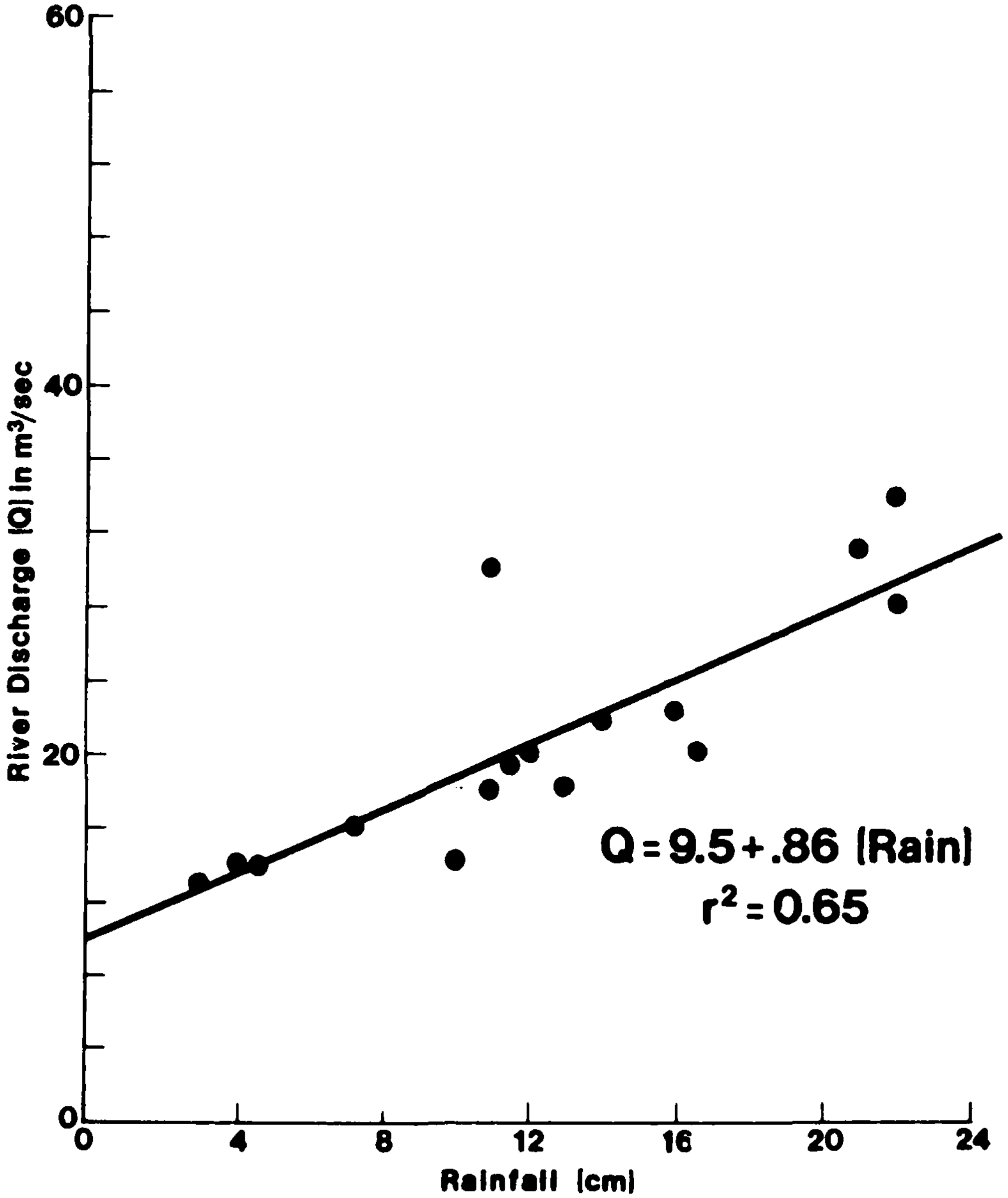


Figure 3. Mean monthly river discharge (m^3/sec) as a function of mean monthly rainfall (cm) for the Tangipahoa River, LA. The results of a regression analysis are indicated.

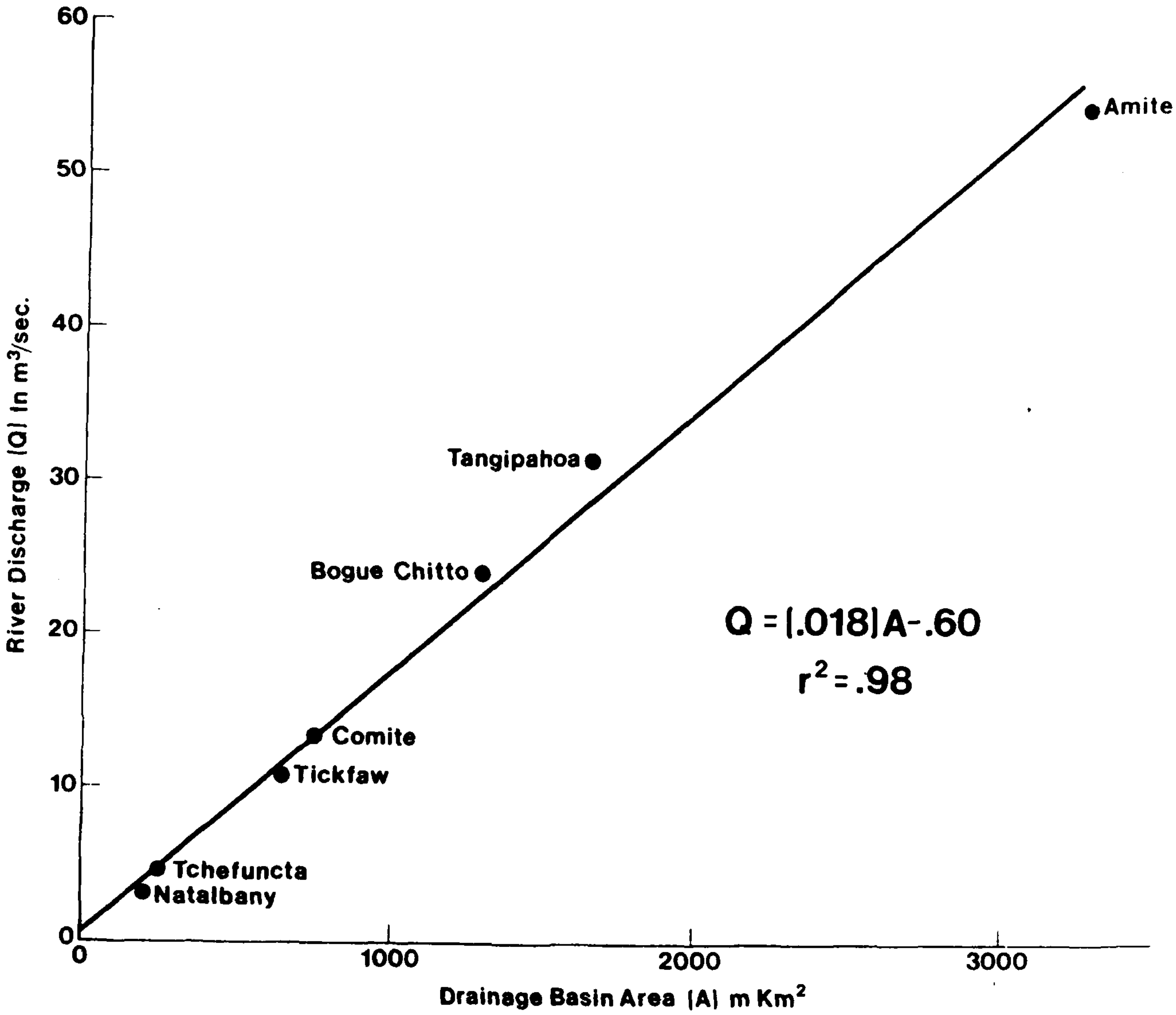


Figure 4. Mean monthly river discharge for selected rivers entering Lake Pontchartrain, LA, in m^3/sec (U.S.G.S. long-term mean) as a function of drainage basin size in Km^2 (from U.S.G.S. records). The results of a regression analysis are indicated.

Table 5. Water Budget for Lake Pontchartrain, LA

Location	Basin area[1] km²	Long term flow[1] m³/sec	Percent of flow	1978 Seasonal Data: Winter[5] m³/sec	Spring[5] m³/sec	Summer[5] m³/sec	Fall[5] m³/sec	Year average m³/sec	Percent of flow
A. RIVER INPUTS									
Lake Maurepas Area									
Tickfaw	640[1]	22[1]	7.8	(65.0)	(26.0)	(14.0)	(9.9)	29.0	8.7
Amite, Comite	4257[1]	147[1]	52.3	(348.0)	(168.0)	(106.0)	(41.0)	166.0	50.1
Other	259[2]	4[3]	1.4	8.7	9.4	12.4	4.0	8.6	2.6
Tchefuncte	247[1]	10[1]	3.6	(19.0)	(12.0)	(5.0)	(3.8)	10.0	3.0
Tangipahoa	1673[1]	69[1]	24.5	(146.0)	(79.0)	(55.0)	(62.0)	86.0	26.0
Bayou Lacombe	180[2]	10[4]	3.6	6.1	6.5	8.6	2.8	6.0	1.8
Bayou Bonfouca, Liberty	166[2]	3[3]	1.1	5.6	5.9	7.9	2.6	5.5	1.7
St. Charles Marsh	137[2]	2[3]	.7	4.6	4.9	6.5	2.1	4.6	1.5
New Orleans East	87[2]	1[3]	.3	2.9	3.1	4.1	1.3	2.8	.8
North Shore	89[2]	3[3]	1.1	2.9	3.1	4.1	1.3	2.8	.8
New Orleans Vicinity	300[2]	10[4]	3.6	10.0	10.8	14.3	4.6	10.0	3.0
TOTAL RIVERS		281	100	618	328	238	135	331	100
B. TIDAL INPUTS[2]									
Rigolets	---	---	---	3000	4125	3750	3375	3562	60
Chef Menteur Pass	---	---	---	2000	2000	2250	1750	2000	33
IHNC	---	---	---	400	410	430	400	410	7
TOTAL TIDAL	---	---	---	5400	6535	6430	5525	5972	100
C. TIDAL OUTPUTS[2]									
Rigolets	---	---	---	3225	---	3000	2500	2908	54
Chef Menteur Pass	---	---	---	2650	---	2000	2000	2050	38
IHNC	---	---	---	400	---	400	400	400	8
TOTAL TIDAL	---	---	---	6275	---	5400	4900	5358	100
D. SUMMARY									
Average Input				6018	---	6668	5660	6303	
Average Output				6275	---	5400	4900	5358	
Difference (In-Out)				-257	---	1268	760	945	
Approximate Percent Error				5	---	23	16	17	

[1]Water resources data for Louisiana, U.S.G.S. Report LA-77-2.

[2]Measured by present study.

[3]Estimated from basin size.

[4]U.S. Army Corps of Engineers 1962.

[5]Estimated from rainfall, except for numbers in parenthesis which come from U.S.G.S. records.

average flow into the lake was used to calculate the tidal range. The results are summarized in Table 6. The calculated range exceeds the known tidal range by approximately 40%, indicating the estimate of the tidal prism is too high.

The error in the estimate of the tidal prism volume is to be expected because of the uncertainty (∿20%) in the tidal transport estimates used in the calculation, as discussed previously.

Using the known tidal range of 11 cm (Outlaw 1979), one would expect the tidal prism to be of the same order as that calculated (10^8), but closer to 1.5×10^8 m^3 as opposed to the calculated 2.7×10^8 m^3. As can be seen in Table 5, there is a net inflow of ∿1000 m^3/sec. Ideally, one would expect the input and the output to be approximately equal. The net inflow is a reflection of the inaccuracy of the transport estimates. Assuming the tidal transport to be on the order of 4000-6000 m^3/sec, the estimates have an error of about 20%.

The water budget calculations indicate that the rivers supply approximately 5% of the volume of water entering the lake. The majority (75%) comes from the Amite-Comite system. As shown in the flushing time calculations, however, the lake is about 35% fresh water. This fact indicates that the water entering the lake through the tidal passes contains a large percentage of fresh water. This fresh water may come from the lake itself (ebb water, which re-enters during the flood) or from other sources, such as the Pearl River. Thus, the tidal passes play an important role in the volume (and salt) balance of the lake.

IV. Salt Budget

The time series data of current speed and salinity collected by both this hydrography group (Chapter 4) and the nekton and plankton

Table 6. Calculation of Tidal Range in Lake Pontchartrain, LA

Area of lake = 640 square miles

$$= 1.66 \times 10^9 \text{ square meters}$$

Volume of water into the lake is (from Table 5)

$$5972 \text{ m}^3/\text{sec} = 2.7 \times 10^8 \text{ m}^3/\text{tidal cycle}$$

If this tidal prism is spread over the entire lake, the average increase in elevation due to the tide is given by:

$$\frac{2.7 \times 10^8 \text{ m}^3}{1.66 \times 10^9 \text{ m}^2} = .16 \text{ meters} = 16 \text{ cm}$$

The WES data collected during 1979 indicated a mean tidal range of $\sim$11 cm (Outlaw 1979).

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group (Chapters 12 and 15) were used to compute a first order salt budget to determine the contribution of each pass.

The salt flux at any given time was computed by multiplying the vertically averaged current speed by the vertically averaged salinity. The result is the advective salt flux at the location. This value was multiplied by the channel cross section to give the total salt flux through the channel. The assumption has been made that the water mass is homogeneous across the channel in order to estimate a crude salt balance. The data from the IHNC were divided into two sections in the vertical to account for the salt wedge.

The salt flux values (in grams/second) were averaged over each half of the tidal cycle and resulted in estimates of the average rates of salt input and output. These rates were computed on a monthly basis.

Assuming a diurnal tide with a half-period of 12.5 hours, the average rates of salt input and output were multiplied by this figure to give the total amount of salt (in grams) that enters and leaves the lake over a tidal cycle. The results are presented in Table 7.

Long-term salinity data (COE 1962) show a seasonal picture with a maximum in the fall and a minimum in the summer. This would indicate a net lakeward transport of salt during summer and a net seaward transport of salt during winter and spring. To observe this pattern, one would need long-term, precise measurements of salt flux because the change occurs over a period of months. The data from this study were collected over a single tidal cycle during each month and do not allow such resolution. During any given tidal cycle, one would expect any net transport of salt to be quite small (a few percent perhaps), thus the

Table 7. Salt Budget for Lake Pontchartrain, LA in 1978–1979

A. INPUT

MONTH	RIGOLETS Avg. Rate in (g/s)	RIGOLETS Input (g/cycle)	CHEF MENTEUR Avg. Rate in (g/s)	CHEF MENTEUR Input (g/cycle)	IHNC - TOP Avg. Rate in (g/s)	IHNC - TOP Input (g/cycle)	IHNC - BOTTOM Avg. Rate in (g/s)	IHNC - BOTTOM Input (g/cycle)	Total Input (g/cycle)
MAY	8.4×10^3	3.8×10^8	13.6×10^3	6.1×10^8	$.4 \times 10^3$	$.2 \times 10^8$	$.4 \times 10^3$	$.2 \times 10^8$	10.3×10^8
JUNE	8.6×10^3	3.8×10^8	3.8×10^3	1.7×10^8	1.0×10^3	$.4 \times 10^8$	1.2×10^3	$.5 \times 10^8$	6.4×10^8
JULY	9.3×10^3	4.2×10^8	2.6×10^3	1.2×10^8	2.7×10^3	1.2×10^8	3.7×10^3	1.7×10^8	8.3×10^8
AUG	(27.4×10^3)	(12.2×10^8)	(19.0×10^3)	(8.5×10^8)	$(.5 \times 10^3)$	$(.2 \times 10^8)$	$(.6 \times 10^3)$	$(.3 \times 10^8)$	(21.3×10^8)
SEPT	5.6×10^3	2.5×10^8	6.6×10^3	2.9×10^8	1.8×10^3	$.8 \times 10^8$	2.2×10^3	1.0×10^8	7.2×10^8
OCT	(————)	(————)	(10.8×10^3)	(4.8×10^8)	$(.8 \times 10^3)$	$(.4 \times 10^8)$	(1.2×10^3)	$(.5 \times 10^8)$	(————)
NOV	(6.6×10^3)	(3.0×10^8)	(7.8×10^3)	(3.5×10^8)	(————)	(————)	(————)	(————)	(————)
DEC	4.6×10^3	2.1×10^8	9.3×10^3	4.2×10^8	$.6 \times 10^3$	$.3 \times 10^8$	$.6 \times 10^3$	$.3 \times 10^8$	6.9×10^8
JAN	7.3×10^3	3.3×10^8	15.3×10^3	6.9×10^8	2.4×10^3	1.1×10^8	2.6×10^3	1.2×10^8	12.5×10^8
FEB	(4.6×10^3)	(2.1×10^8)	(2.3×10^3)	(1.0×10^8)	$(.3 \times 10^3)$	$(.1 \times 10^8)$	$(.3 \times 10^3)$	$(.1 \times 10^8)$	(3.3×10^8)

B. OUTPUT

	Avg. Rate in (g/s)	Output (g/cycle)	Avg. Rate in (g/s)	Output (g/cycle)	Avg. Rate in (g/s)	Output (g/cycle)	Avg. Rate in (g/s)	Output (g/cycle)	Total Output (g/cycle)
MAY	4.9×10^3	2.2×10^8	17.0×10^3	7.6×10^8	$.9 \times 10^3$	$.4 \times 10^8$	$.9 \times 10^3$	$.4 \times 10^8$	10.6×10^8
JUNE	4.9×10^3	2.2×10^8	4.8×10^3	2.2×10^8	$.5 \times 10^3$	$.2 \times 10^8$	$.5 \times 10^3$	$.2 \times 10^8$	4.8×10^8
JULY	4.3×10^3	1.9×10^8	9.2×10^3	4.1×10^8	1.7×10^3	$.8 \times 10^8$	1.6×10^3	$.7 \times 10^8$	7.5×10^8
AUG	(————)	(————)	(2.2×10^3)	(1.0×10^8)	$(.5 \times 10^3)$	$(.2 \times 10^8)$	$(.5 \times 10^3)$	$(.2 \times 10^8)$	(————)
SEPT	2.6×10^3	1.2×10^8	5.0×10^3	2.2×10^8	$.7 \times 10^3$	$.3 \times 10^8$	$.9 \times 10^3$	$.4 \times 10^8$	4.1×10^8
OCT	(6.2×10^3)	(2.8×10^8)	(9.2×10^3)	(4.1×10^8)	$(.4 \times 10^3)$	$(.2 \times 10^8)$	$(.4 \times 10^3)$	$(.2 \times 10^8)$	(7.3×10^8)
NOV	(11.7×10^3)	(5.3×10^8)	(7.1×10^3)	(3.2×10^8)	(————)	(————)	(————)	(————)	(————)
DEC	22.4×10^3	10.1×10^8	1.7×10^3	$.8 \times 10^8$	$.2 \times 10^3$	$.1 \times 10^8$	$.2 \times 10^3$	$.1 \times 10^8$	11.1×10^8
JAN	6.4×10^3	2.9×10^8	11.5×10^3	5.2×10^8	$.4 \times 10^3$	$.2 \times 10^8$	$.4 \times 10^3$	$.2 \times 10^8$	8.5×10^8
FEB	(————)	(————)	8.9×10^3	(4.0×10^8)	$(.3 \times 10^3)$	$(.1 \times 10^8)$	$(.3 \times 10^3)$	$(.1 \times 10^8)$	(————)

C. YEARLY SUMMARY

Tidal Pass	Average Input (g/cycle)	% of Total	Average Output (g/cycle)	% of Total	Avg. Input into Lake (g/cycle)	Avg. Output from Lake (g/cycle)	Surplus In-Out	% Surplus
RIGOLETS	3.3×10^8	39	3.4×10^8	44				
CHEF	3.8×10^8	44	3.7×10^8	48	8.6×10^8	7.7×10^8	9×10^7	~10
IHNC-TOP	$.7 \times 10^8$	8	$.3 \times 10^8$	4				
IHNC-BOTTOM	$.8 \times 10^8$	9	$.3 \times 10^8$	4				

amount of salt in should essentially balance the amount of salt out. The data in Table 6 show an imbalance of 10 to 60%. This imbalance is primarily due to both the measurement inaccuracy and the assumption of cross-channel homogeneity and is indicative of the rather large error in the estimates of salt flux. To accurately determine fluxes, an array of meters is necessary to account for the spatial (cross-channel) distribution of the salt flux. Such a measurement scheme was not part of this study.

These data represent a first attempt to rank the passes based on the contribution of each to the total salt budget as opposed to a quantitative determination of the salt balance within the lake. To accomplish this, the average inputs and outputs for each of the passes were computed from the monthly data. This average figure indicates that The Rigolets and the Chef Menteur Pass each supply about 40% of the total salt, and the IHNC supplies about 20%. The average figures show an imbalance of about 10%, which indicates that these percent contributions are reasonable.

Future study should include long-term (∿1 year) monitoring of the volume and salt fluxes through the tidal passes to construct a quantitative salt balance for the system. A possible means of monitoring volume flux is discussed in Appendix 3.

V. Energy Budget

A. Introduction

The dominant circulation energy sources for Lake Pontchartrain are the winds and the tides. River input may be important in the form of "impulsive events" (i.e., floods). However, for this budget we will concern ourselves with an "average" tidal cycle in which river effects will be considered negligible.

The use of the energy budget provides a possible means of evaluating the relative importance of the wind and tide effects (for a first approximation).

B. Energy Balance

Following the work of Taylor (1919), the amount of energy entering the system through a channel is given by:

$$E_i = \rho g dt \int DhV\mathrm{SIN}\theta ds + \int 1/2\rho V\mathrm{SIN}\theta dt\ (2gh^2 + DV^2 + hV^2)ds$$

where:

ρ = density of water
g = acceleration due to gravity
D = depth to bottom
h = tidal height
V = current velocity
ds = element along the curve describing a transect over the water surface
θ = angle between ds and current direction

Taylor worked in the Irish Sea, where h was small compared to D, and he was able to neglect the second integral. This assumption will also hold in Lake Pontchartrain (D = 3.5 m, h = .2m); hence, the energy input is given by:

$$E_i = \rho g dt \int DhV\mathrm{SIN}\theta ds$$

Taylor further simplified this by assuming that his study area (the Irish Sea) had currents that could be expressed by a cosine function. Hence, he was able to determine a tidally averaged expression for the energy entering the system.

In the case of Lake Pontchartrain, I have used current data collected over a tidal cycle in two of the tidal passes. The IHNC was not included because the volume flow, hence the tidal energy flow, through this pass is small. From them it is possible to compute the energy

input as a function of time over a tidal cycle, a procedure followed by Hart and Murray (1978). I have not included the work done on or by the moon that Taylor included in his calculations. This can be justified because the tidal ranges are small in the lake.

A time series of the current and tidal height data used to calculate the energy input into the lake as well as the time series of energy input is shown in Figure 5. It is evident that most of the energy enters through The Rigolets. The average rate of energy entering the lake can be determined by taking the average of all the positive values in Figure 5. Similarly, the average rate of energy leaving the lake can be computed by taking the average of all the negative values in Figure 5. The calculation yields the following results:

	Energy in ergs/sec	Energy out ergs/sec
The *Rigolets*	3.80×10^{13}	3.20×10^{13}
Chef Menteur Pass	3.23×10^{12}	4.97×10^{12}

It is interesting to note that tidal energy entering by the Chef Menteur Pass is only about 8% of the amount entering by The Rigolets. Since the energy is proportional to the ratio of channel width and velocity, one would expect the Chef Menteur Pass to be about 25% less than The Rigolets. The measured difference is only 8%. This is probably the result of diurnal inequality in the flow, since the measurements in each pass were not simultaneous.

Trask (1979) has shown that in order to properly evaluate an energy budget, one should have at least a 14-day record to account for the diurnal inequality. Errors of $\sim$25% could result if one did not average over a spring/neap cycle.

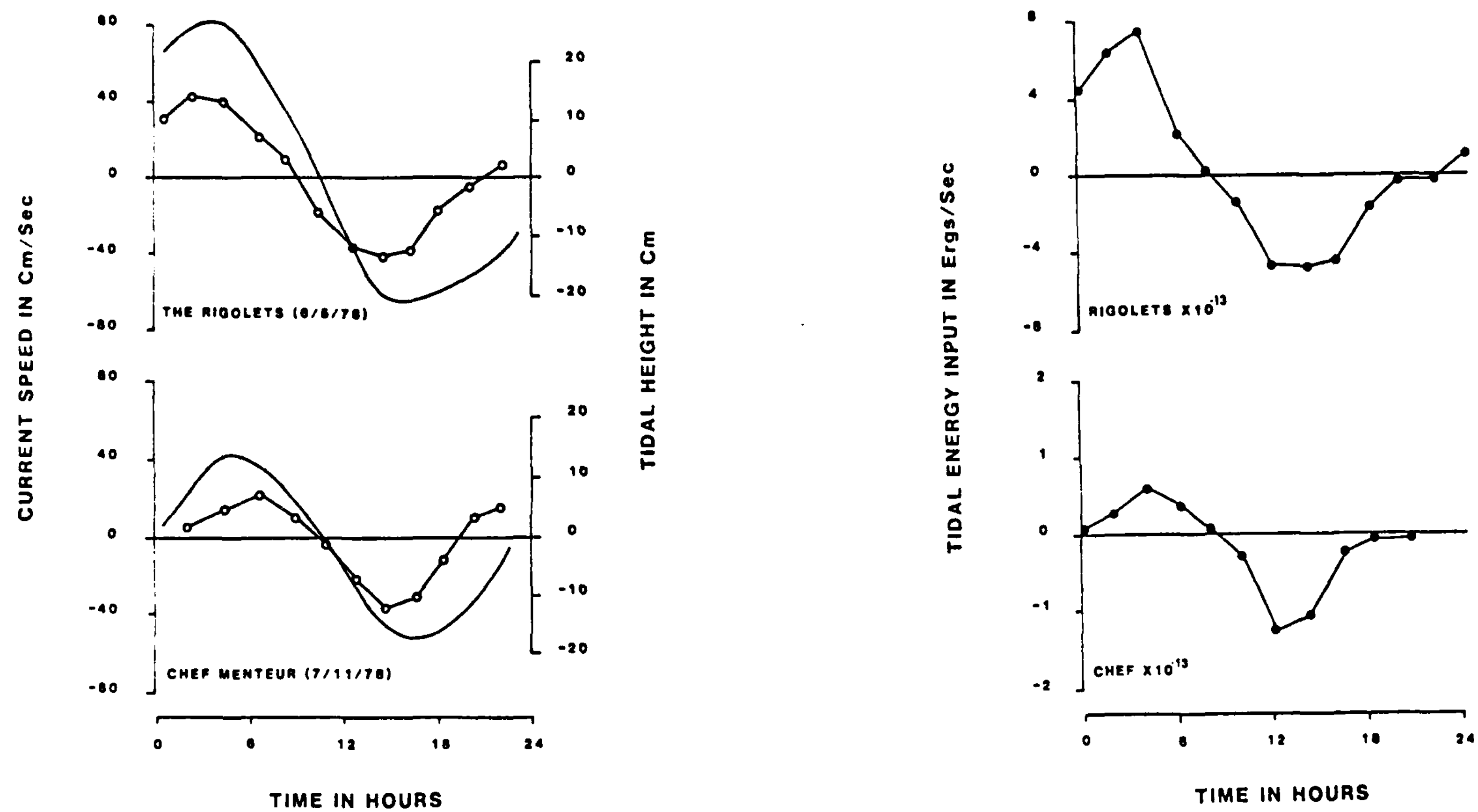

Figure 5. Time series of currents (solid line) and tidal height (circles) for The Rigolets tidal pass and the Chef Menteur tidal pass in Lake Pontchartrain, LA (left); and the corresponding time series data of energy input (right) computed from the tide height and current data. The locations and dates are indicated at the origins on the current and tidal height series.

C. Estimation of Wind Effects

The analysis presented thus far has only been concerned with tidal effects. The effect of wind stress can be investigated by assuming that the rate of energy transfer from the wind to the lake given by Hart and Murray (1978):

$$E_w \sim .05\, W\tau$$

where:

W = wind speed

τ = wind stress

Using this formula with various wind speeds, the energy imparted to the lake can be calculated and compared to the tidal input already calculated. The result will give a means by which to access the relative importance of winds and tides. I have used the following formula for wind stress (from McLellan 1965):

$$\tau = \gamma_{10}^2\, \rho_a\, U_{10}^2$$

where:

τ = wind stress

ρ_a = density of air

U_{10} = wind speed

γ_{10}^2 = resistance coefficient

$\sim 1.5 \times 10^{-3}$ for light winds

$\sim 2.4 \times 10^{-3}$ for strong winds

The results of the calculation are shown in Table 8.

D. Summary and Discussion

The energy balance calculated is a crude first approximation based on data over a single tidal cycle in each of the three tidal passes. A

Table 8. Comparison of Wind Energy to Tidal Energy in Lake Pontchartrain, LA

Wind m/s	τ^{*} dynes/cm^2	Ew** ergs/cm^2/sec	Ew lake total X 10^{14} ergs/s	Ew:Et***
1	.02	.10	.02	.05
2	.10	1.00	.20	.48
3	.18	2.70	.45	1.21
4	.36	7.20	1.20	2.90
5	.63	15.75	2.61	6.3
6	.91	27.30	4.53	10.98
7	1.30	45.50	7.55	18.31
8	1.76	70.40	11.70	28.34
9	2.23	99.00	16.43	39.80
10	2.76	138.00	23.00	55.78

*Wind stress given by (McLellan 1965):

$$\tau = \gamma^2 10 \rho_a U_{10}^2$$

where γ = wind stress

ρ_a = density of air

U_{10} = wind at 10 m above surface

γ_{10}^2 = resistance coefficient

$\sim 1.5 \times 10^{-3}$ for light winds

$\sim 2.4 \times 10^{-3}$ for strong winds

**Wind energy (Ew) given by (Hart and Murray 1978):

$$Ew \sim .05 \tau W$$

where: τ = wind stress

W = wind speed

***Et = total tidal energy input into the system (4.30×10^{12} ergs/sec).

proper budget should be based upon at least a one-month time series to allow for diurnal inequalities (such data were not available). In addition, such a time series would allow one to average wind-induced transport throughout the passes. However, it can be reasonably assumed that the estimate of the energy input is of the correct order (10^{13}). Thus, the comparison between the tidal and the wind energy is justified. The results indicate that the tides predominate over winds in the range of 1 to 2 m/sec, winds and tides are about equal for winds in the range of 2 to 3 m/sec, and winds predominate for wind speeds in excess of 3 m/sec.

Loading Rangia shells on barge from dredge

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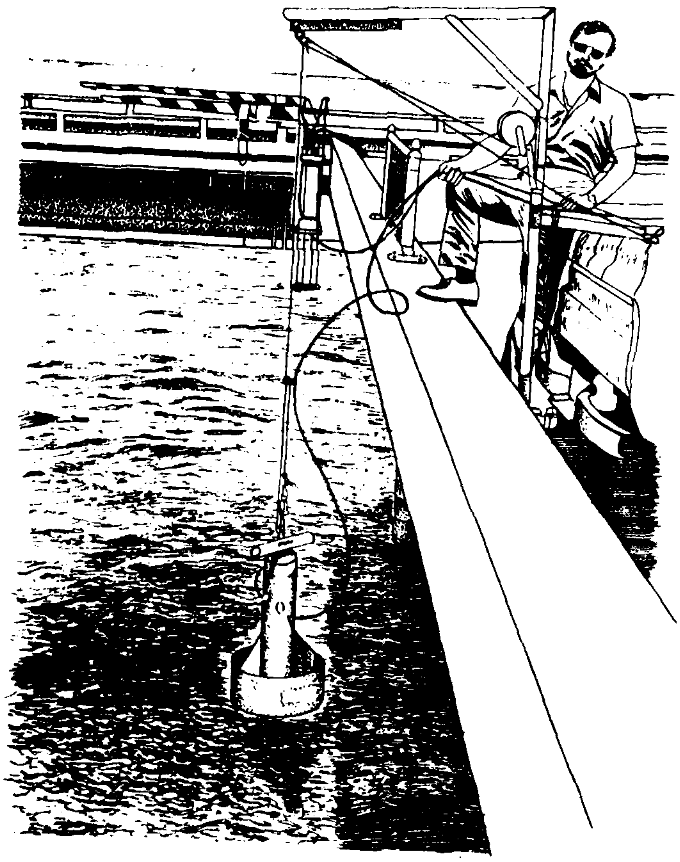


Measuring water currents from Lake Pontchartrain Causeway

APPENDIX 1

Selected Data on Currents, Temperature, and Conductivity

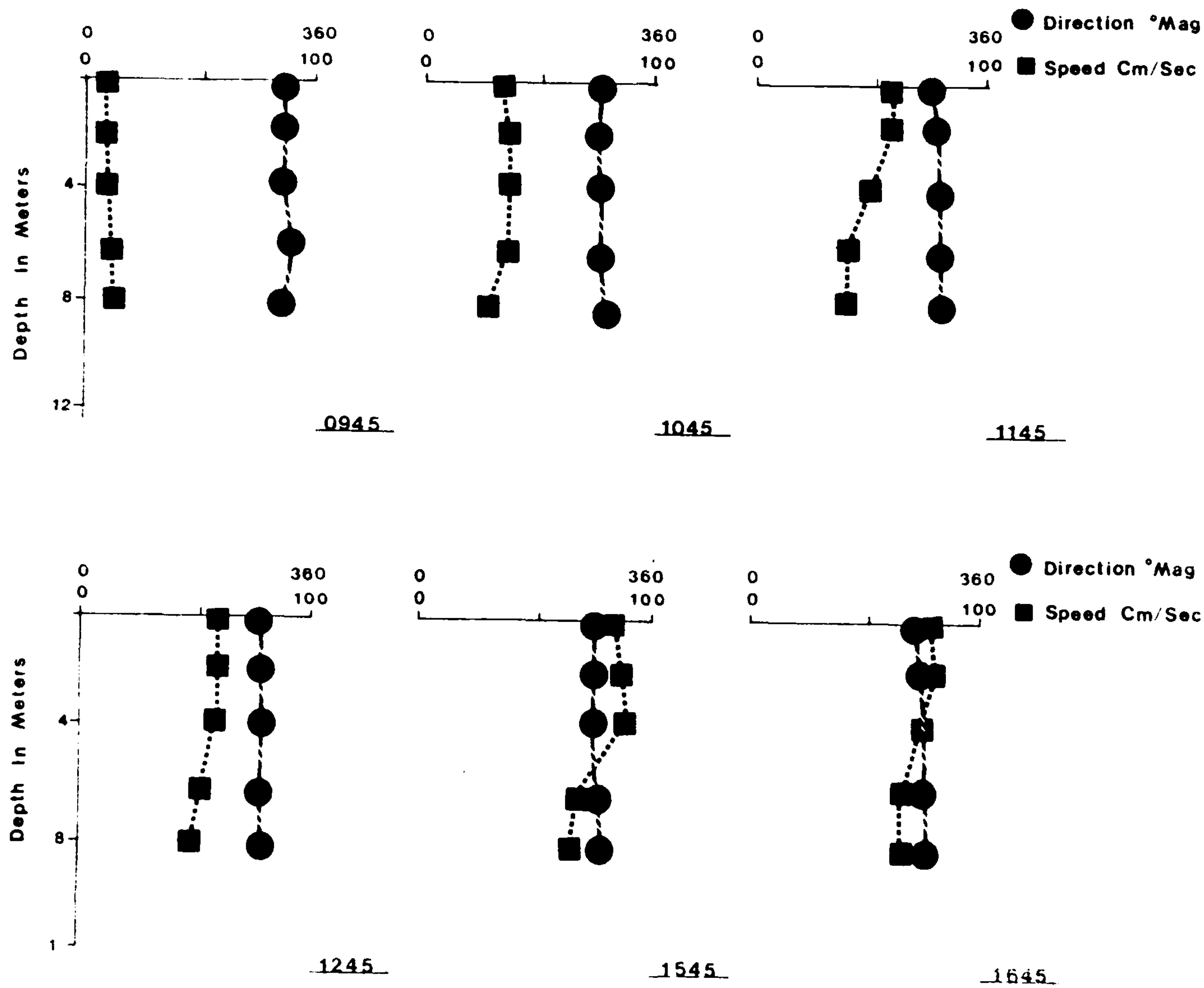


Figure A1-1. Current speed (cm/sec) and direction (°Mag) profile plots from The Rigolets tidal pass for April 27, 1978. The time of the profile is indicated at the lower right of each plot.

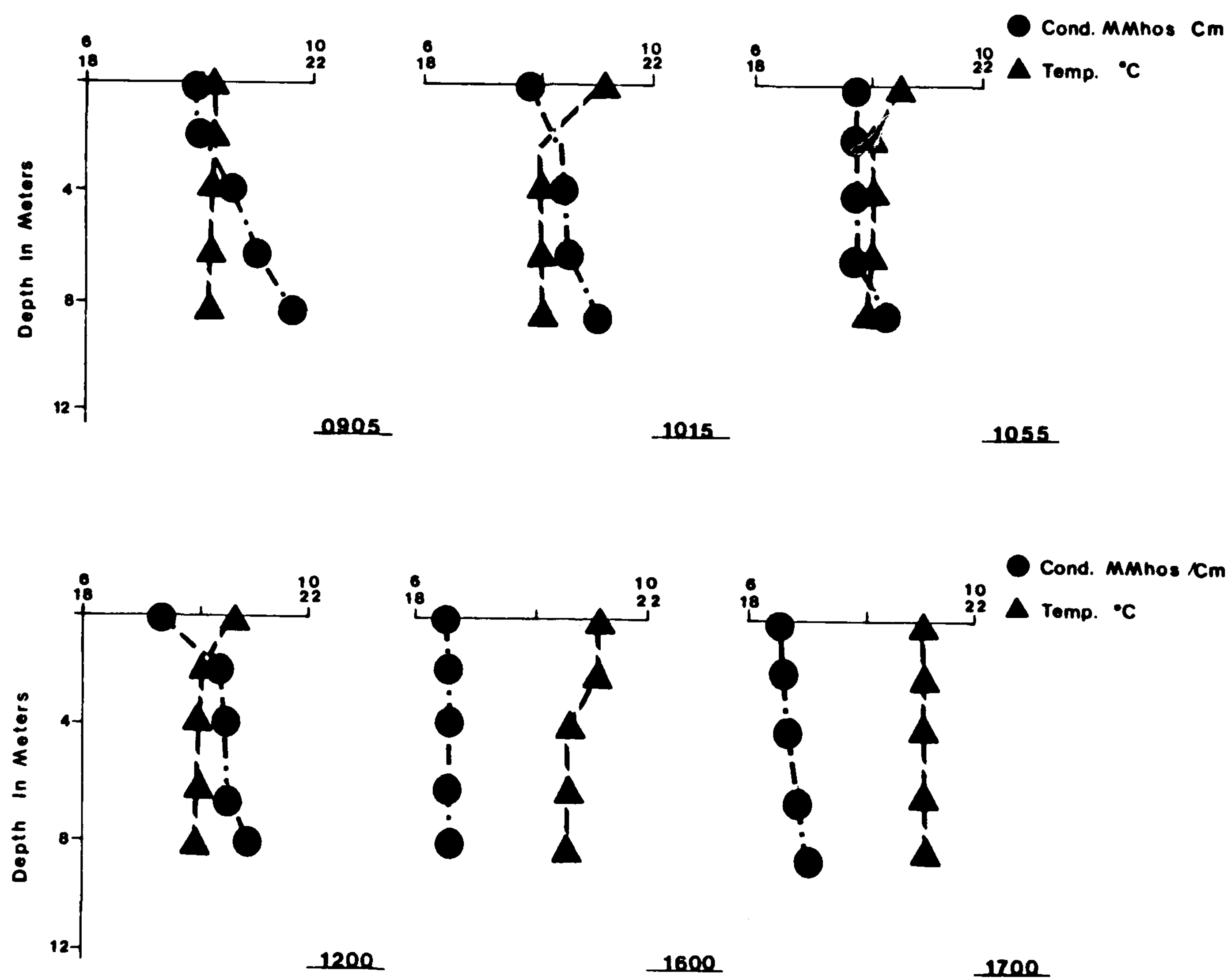


Figure A1-2. Conductivity (mmhos/cm) and temperature (°C) profile plots from The Rigolets tidal pass for April 27, 1978. The time of the profile is indicated at the lower right of each plot.

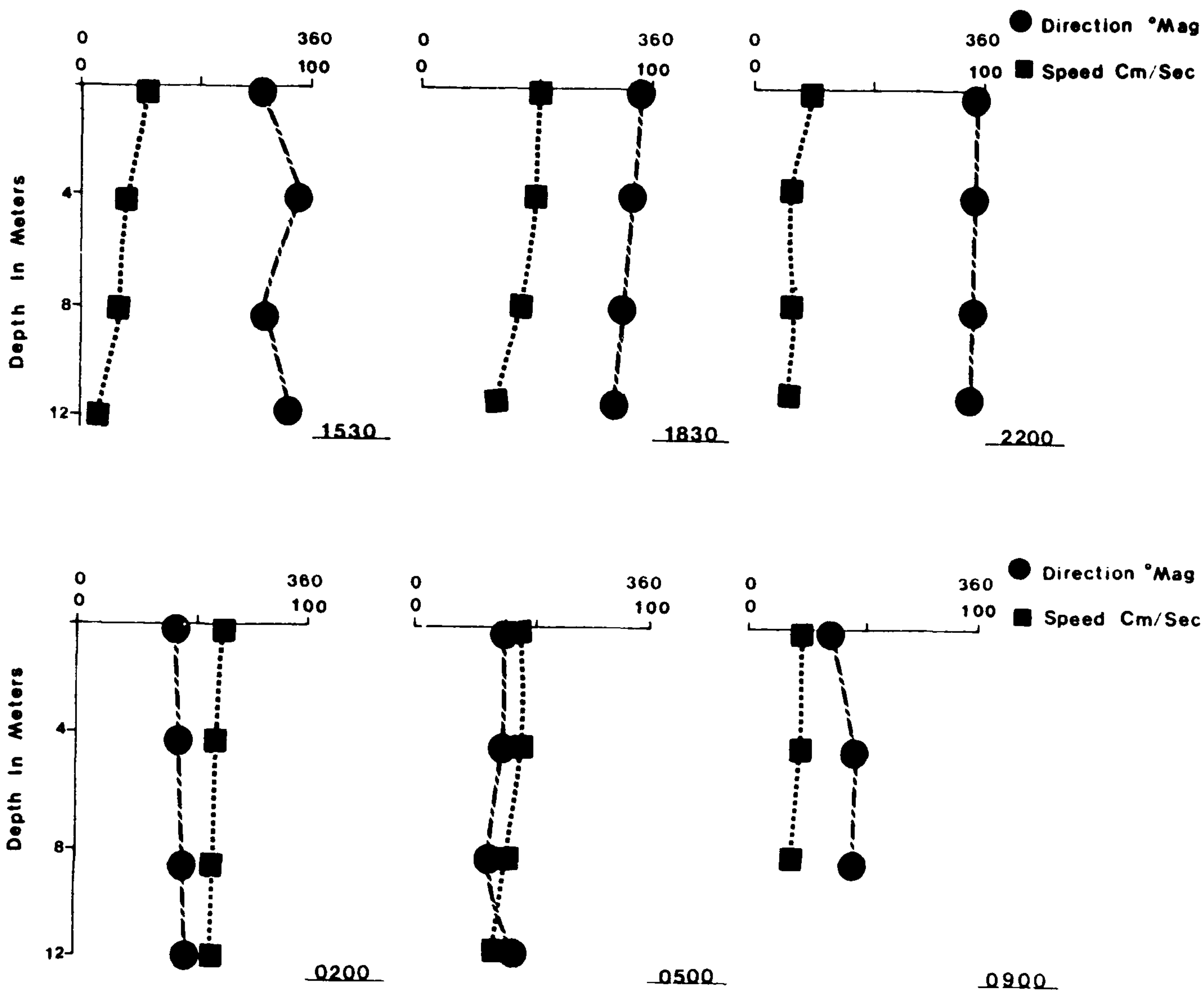


Figure A1-3. Current speed (cm/sec) and direction (°Mag) profile plots from Chef Menteur Pass for July 11, 1978 (top) and July 12, 1978 (bottom). The time of the profile is indicated at the lower right of each plot.

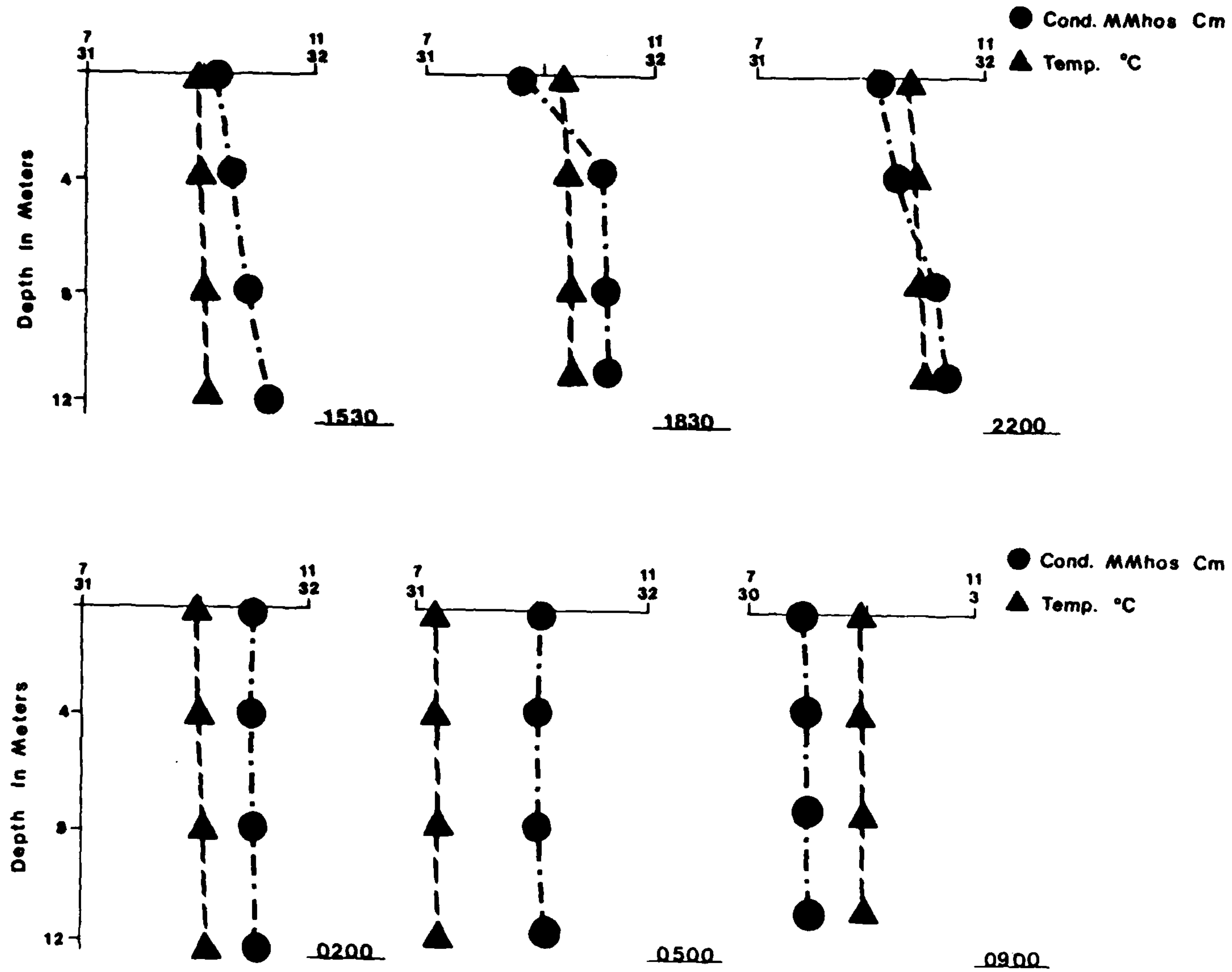


Figure A1-4. Conductivity (mmhos/cm) and temperature (°C) profile plots from Chef Menteur Pass for July 11, 1978 (top) and July 12, 1978 (bottom). The time of the profile is indicated at the lower right of each plot.

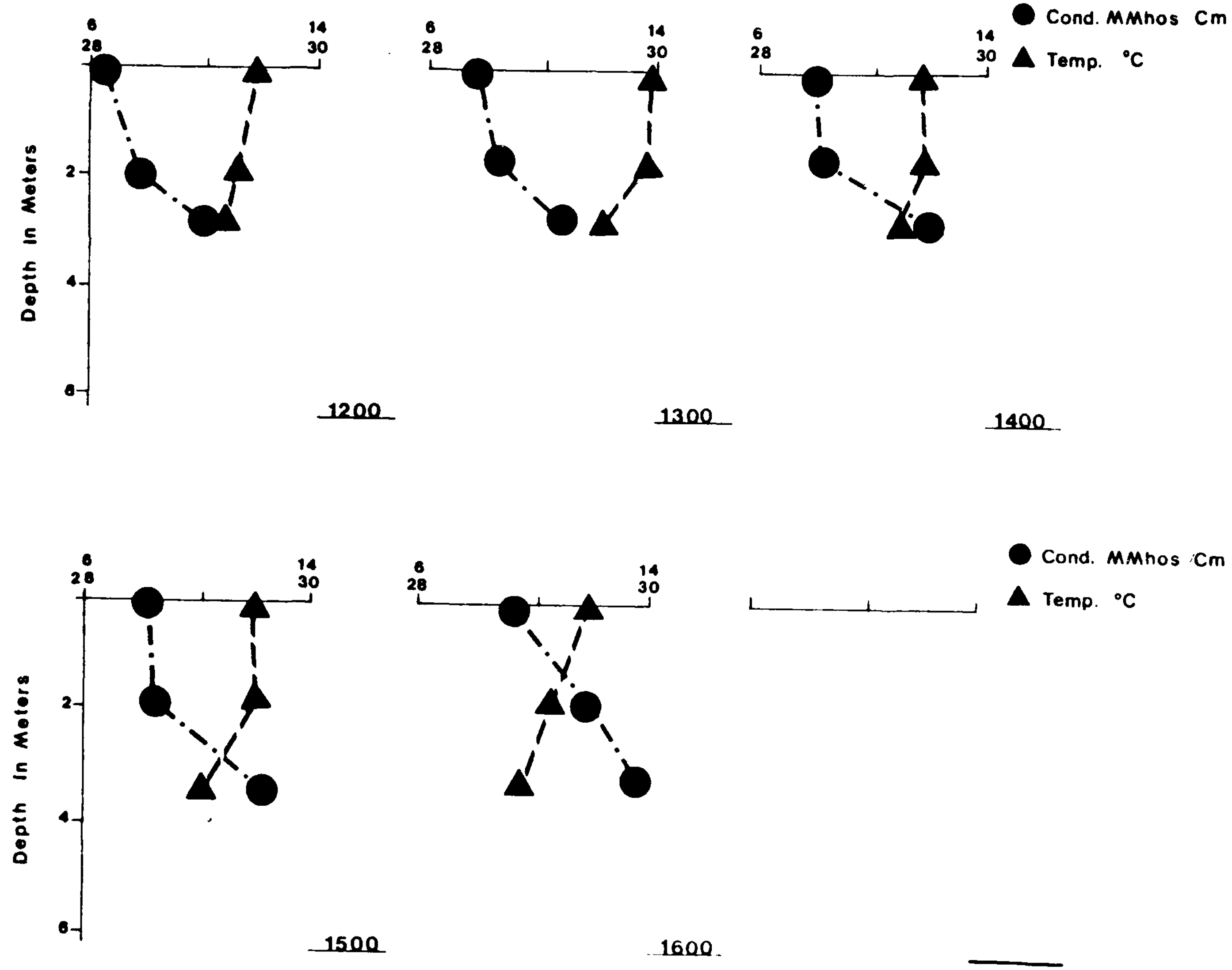


Figure A1-5. Current speec (cm/sec) and direction (°Mag) profile plots from the Inner Harbor Navigation Canal (IHNC) for June 22, 1978. The time of the profile is indicated at the lower right of each plot.

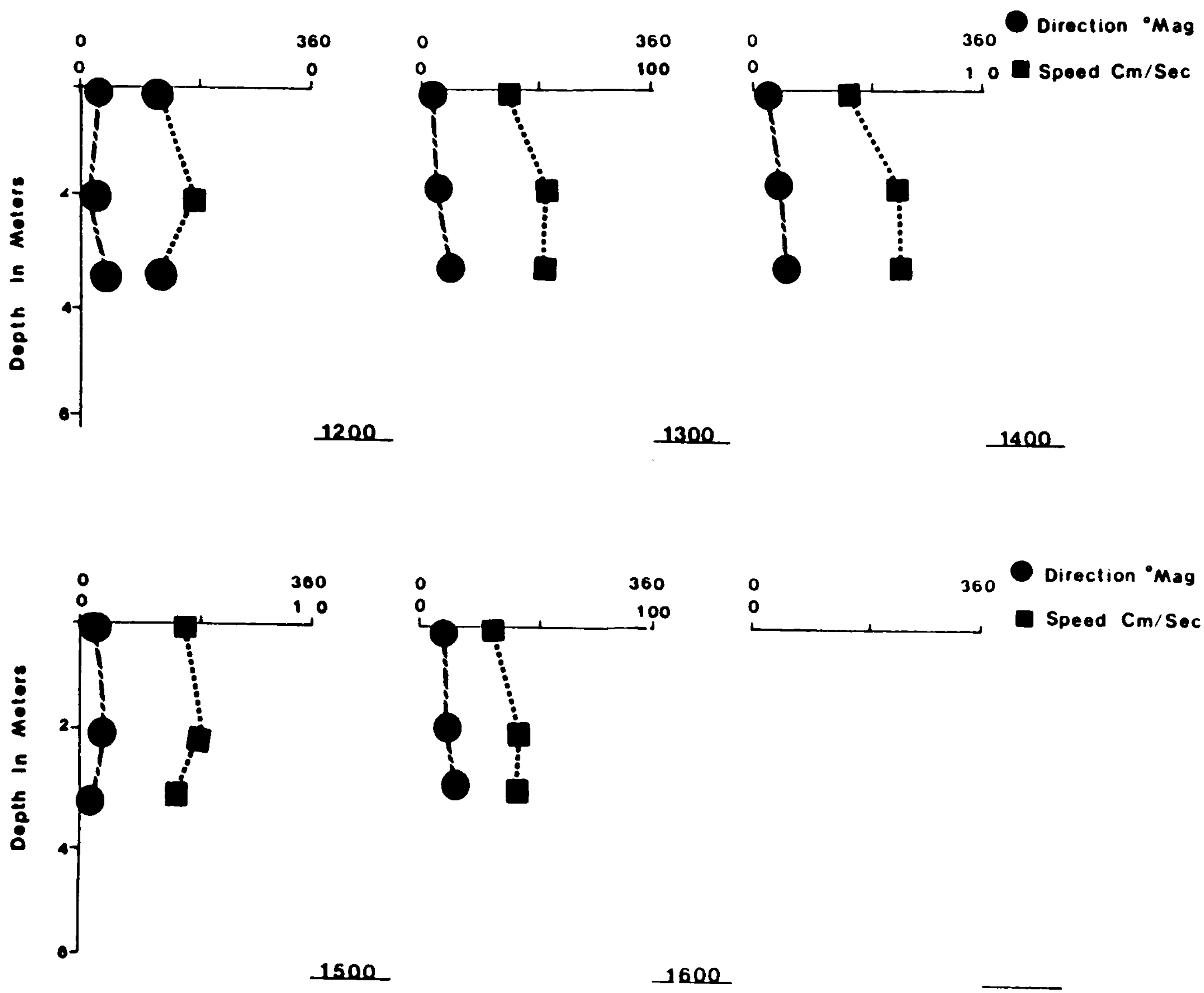


Figure A1-6. Conductivity (mmhos/cm) and temperature (°C) profile plots from the Inner Harbor Navigation Canal (IHNC) for June 22, 1978. The time of the profile is indicated at the lower right of each plot.

APPENDIX 2

Current Speed and Direction
and
Conductivity and Temperature
Time Series Plots

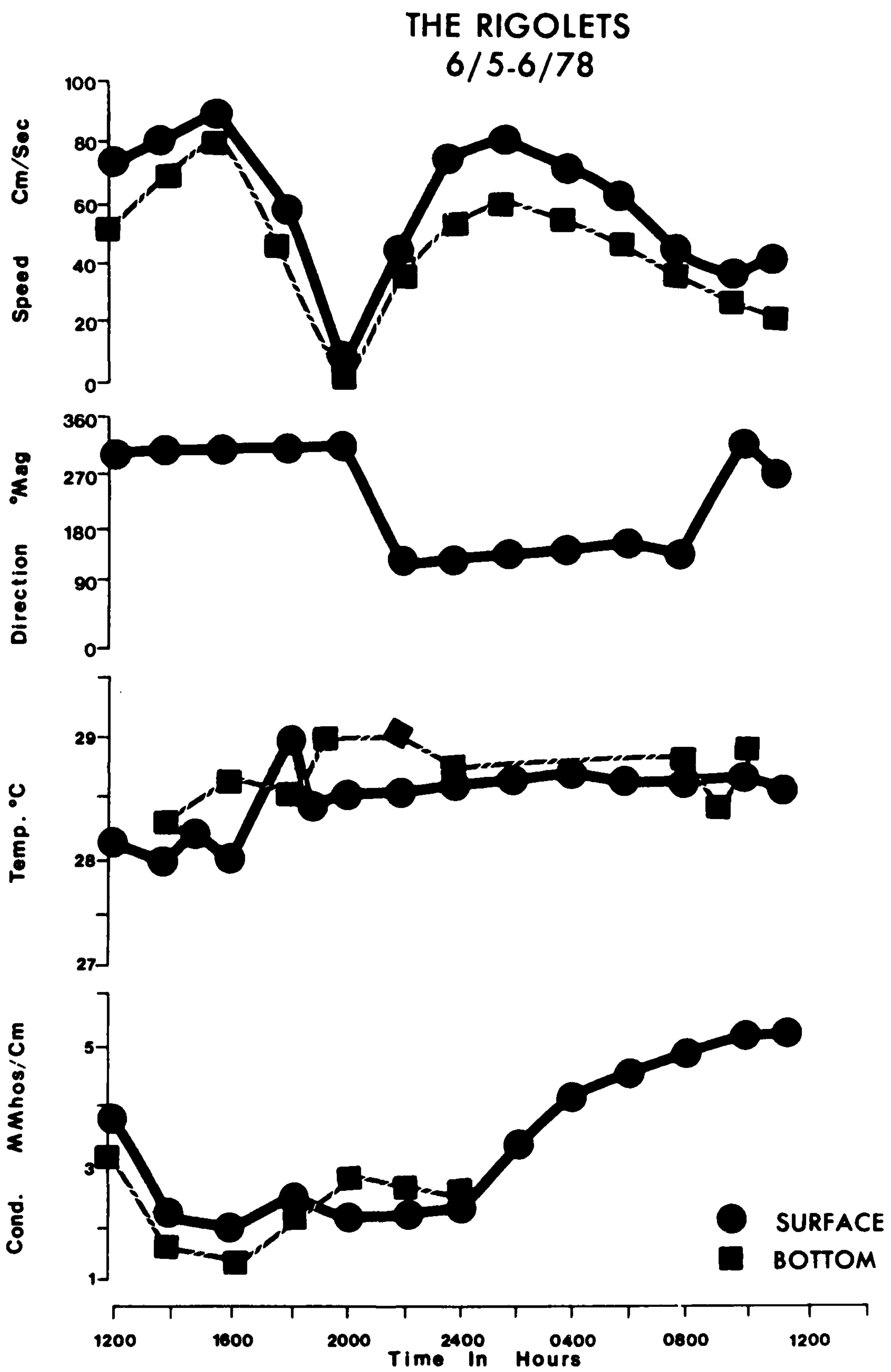


Figure A2-1. Time series plots of (top to bottom): current speed (cm/sec), current direction (°Mag), temperature (°C), and conductivity (mmhos/cm), for The Rigolets Pass on July 5-6, 1978. Surface and near bottom values are given.

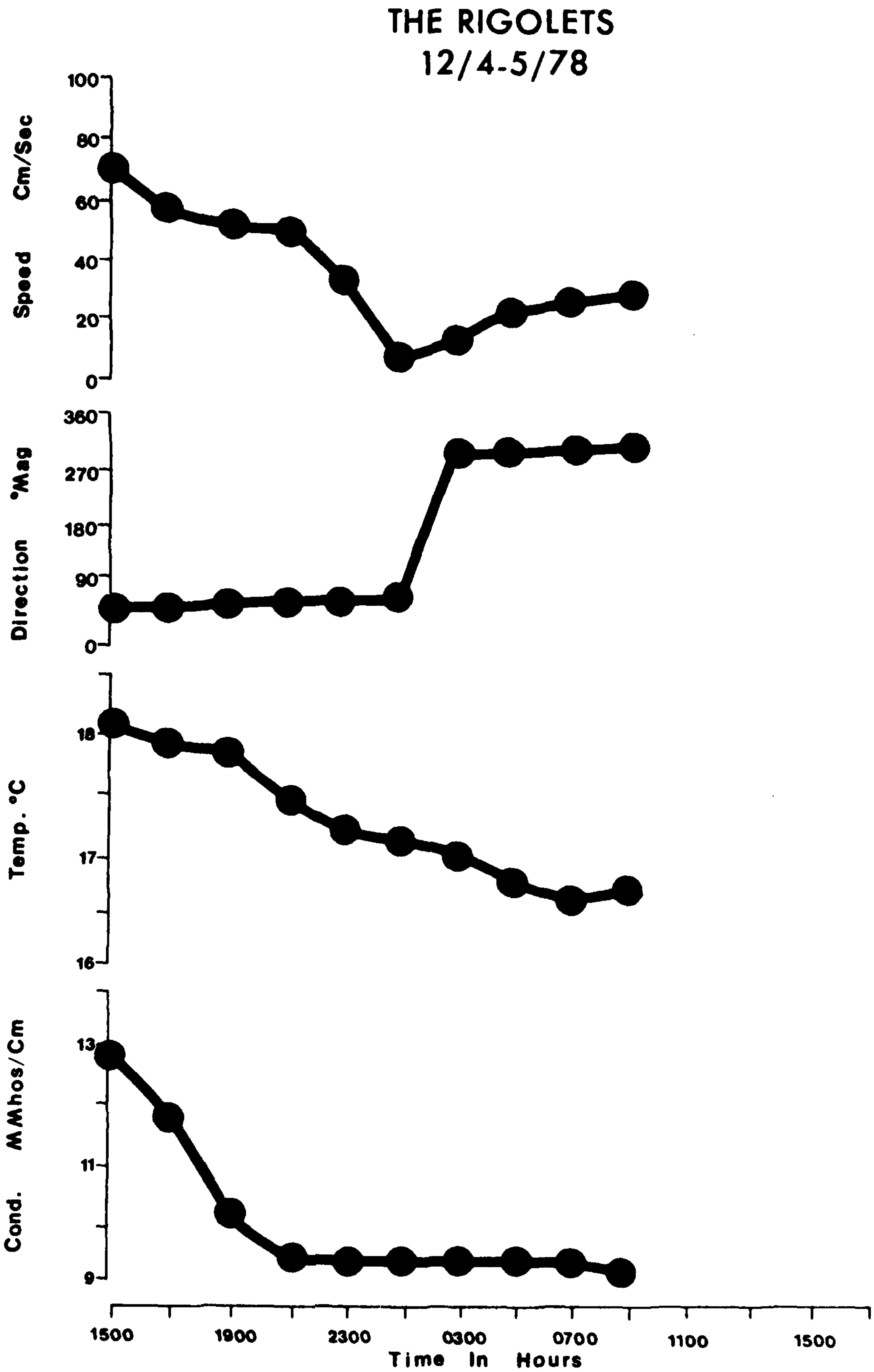


Figure A2-2. Time series plots of (top to bottom): current speed (cm/sec), current direction (°Mag), temperature (°C), and conductivity (mmhos/cm) for The Rigolets on December 4-5, 1978. Values are verticle averages.

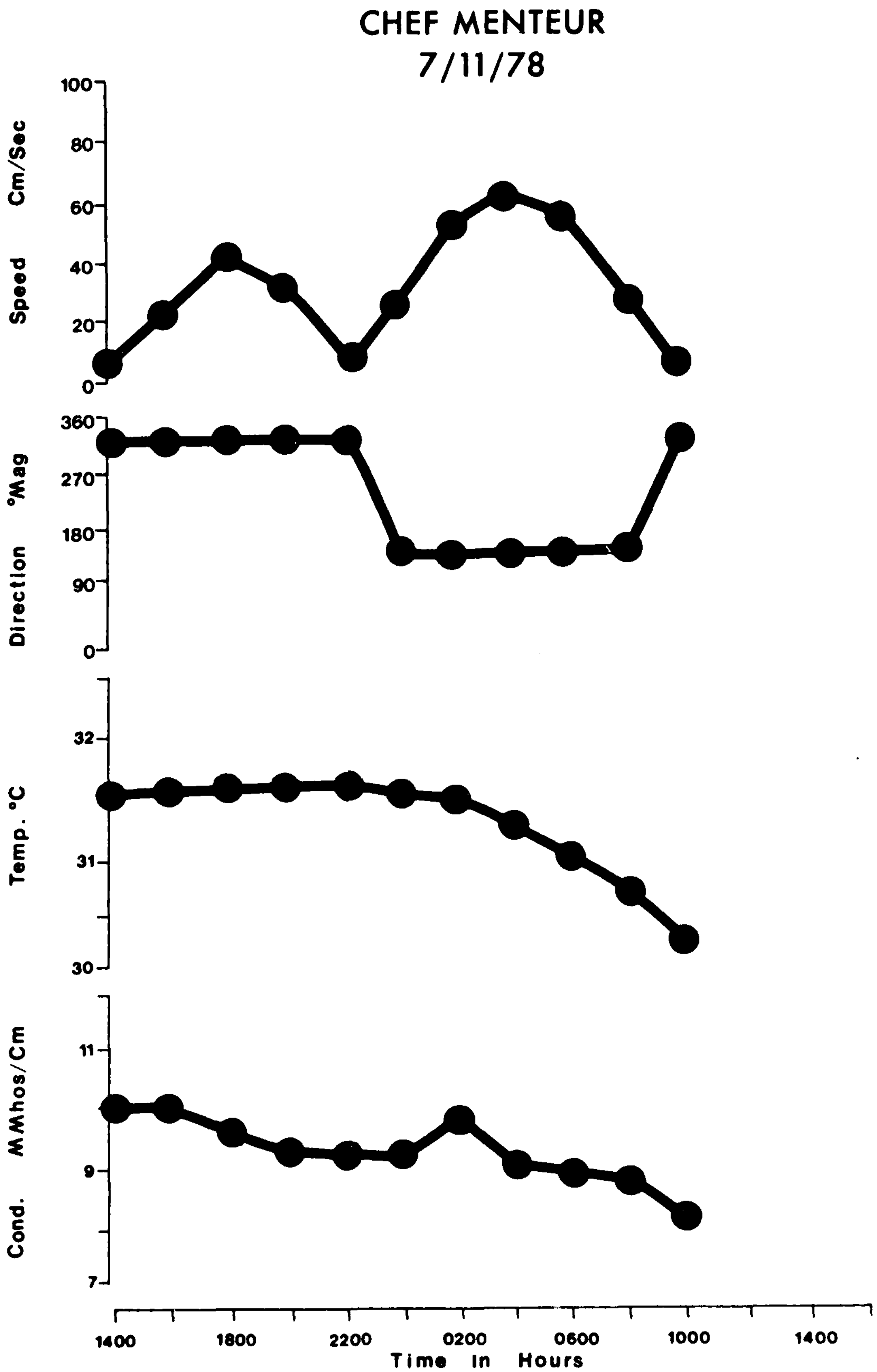


Figure A2-3. Time series plots of (top to bottom): current speec (cm/sec), current direction (° Mag), temperature (°C), and conductivity (mmhos/cm) for the Chef Menteur Pass on July 11, 1978. Values are verticle averages.

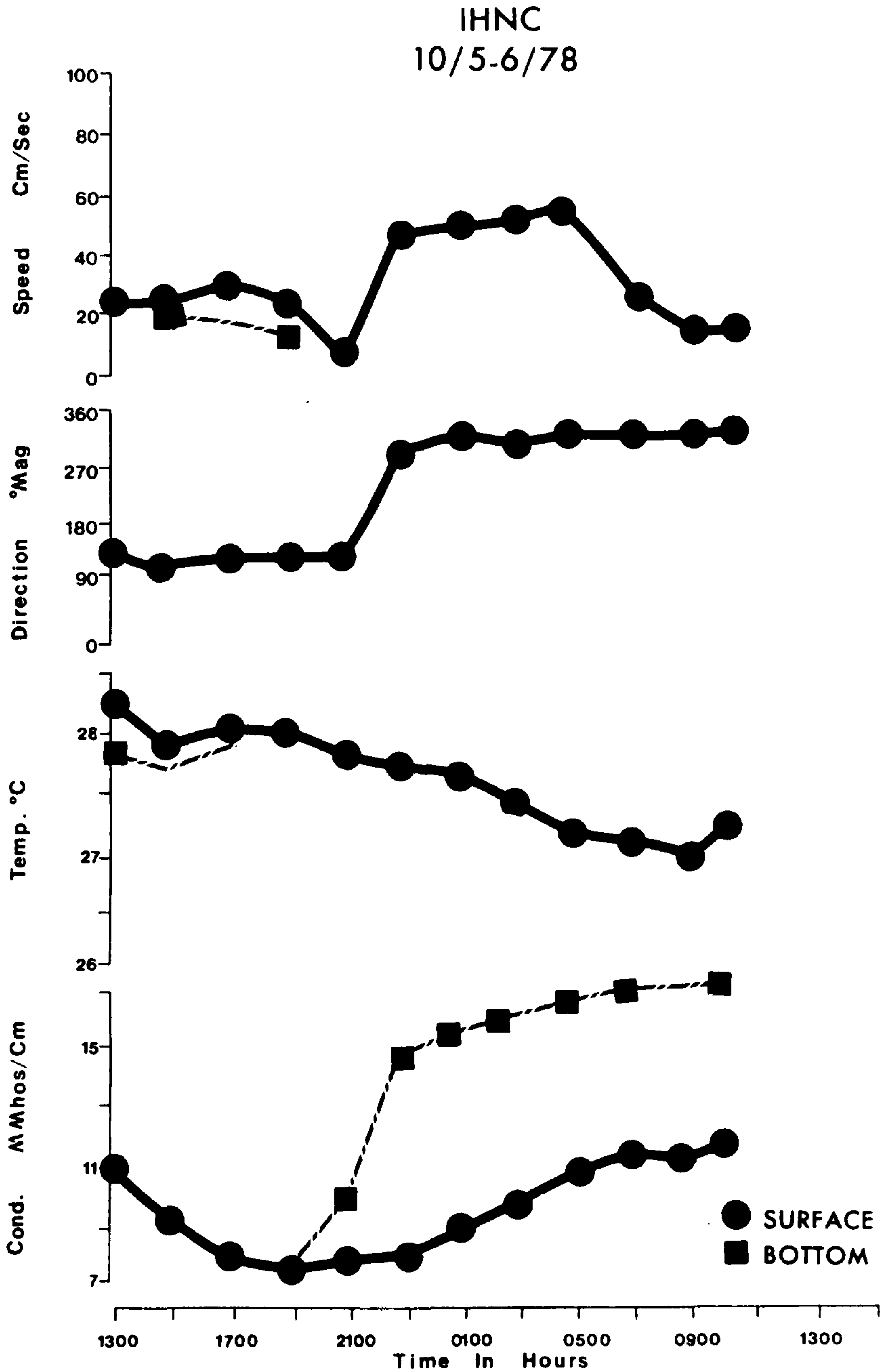


Figure A2-4. Time series plots of (top to bottom): current speed (cm/sec), current direction (°Mag), temperature (°C), and conductivity (mmhos/cm) for the Inner Harbor Navigation Canal (IHNC) on October 5-6, 1978. Surface and near bottom values are given.

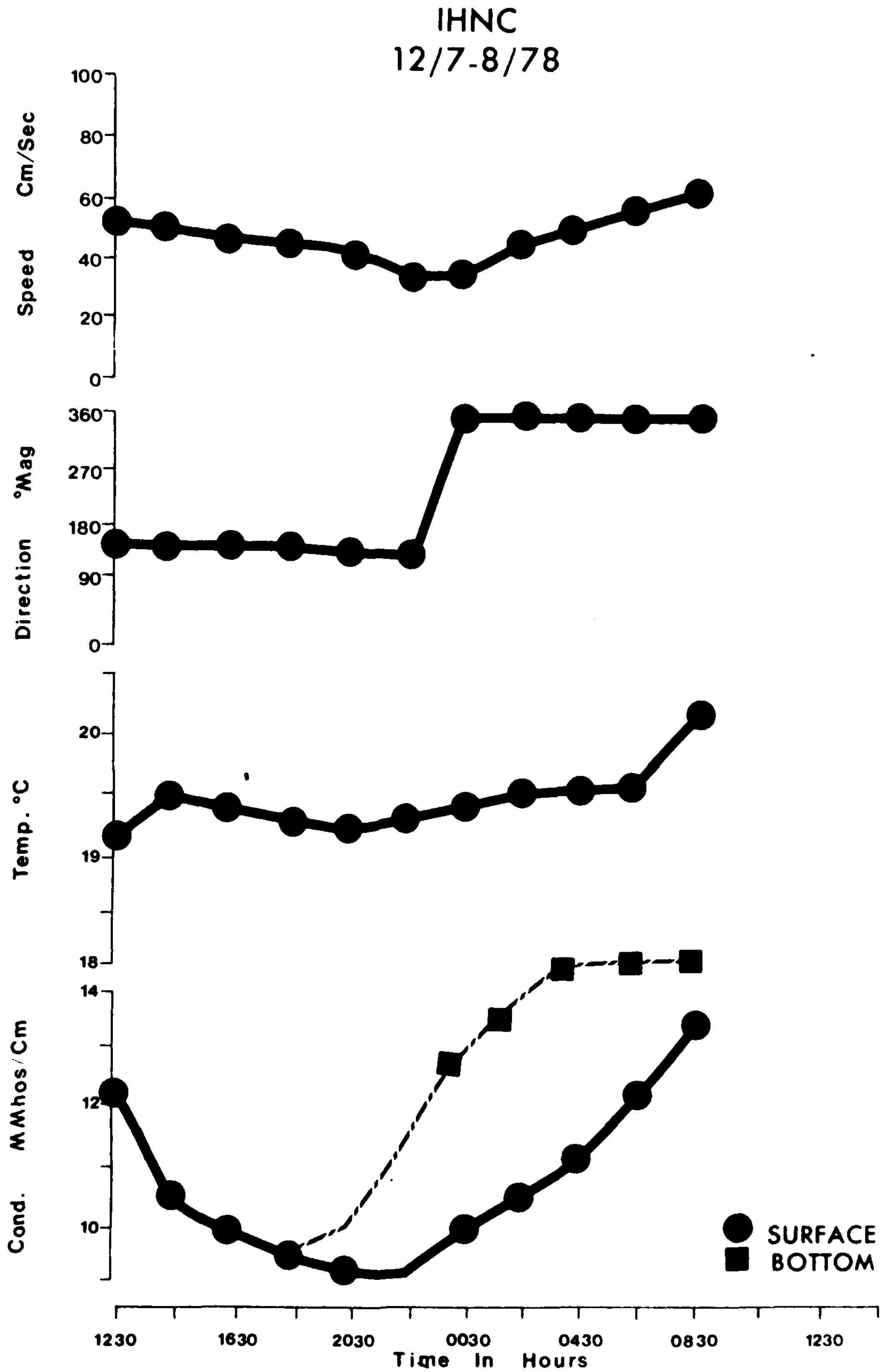


Figure A2-5. Time series plots of (top to bottom): current speed (cm/sec), current direction (°Mag), temperature (°C), and conductivity (mmhos/cm) for the Inner Harbor Navigation Canal (IHNC) on December 7-8, 1978. Surface and near bottom values are given.

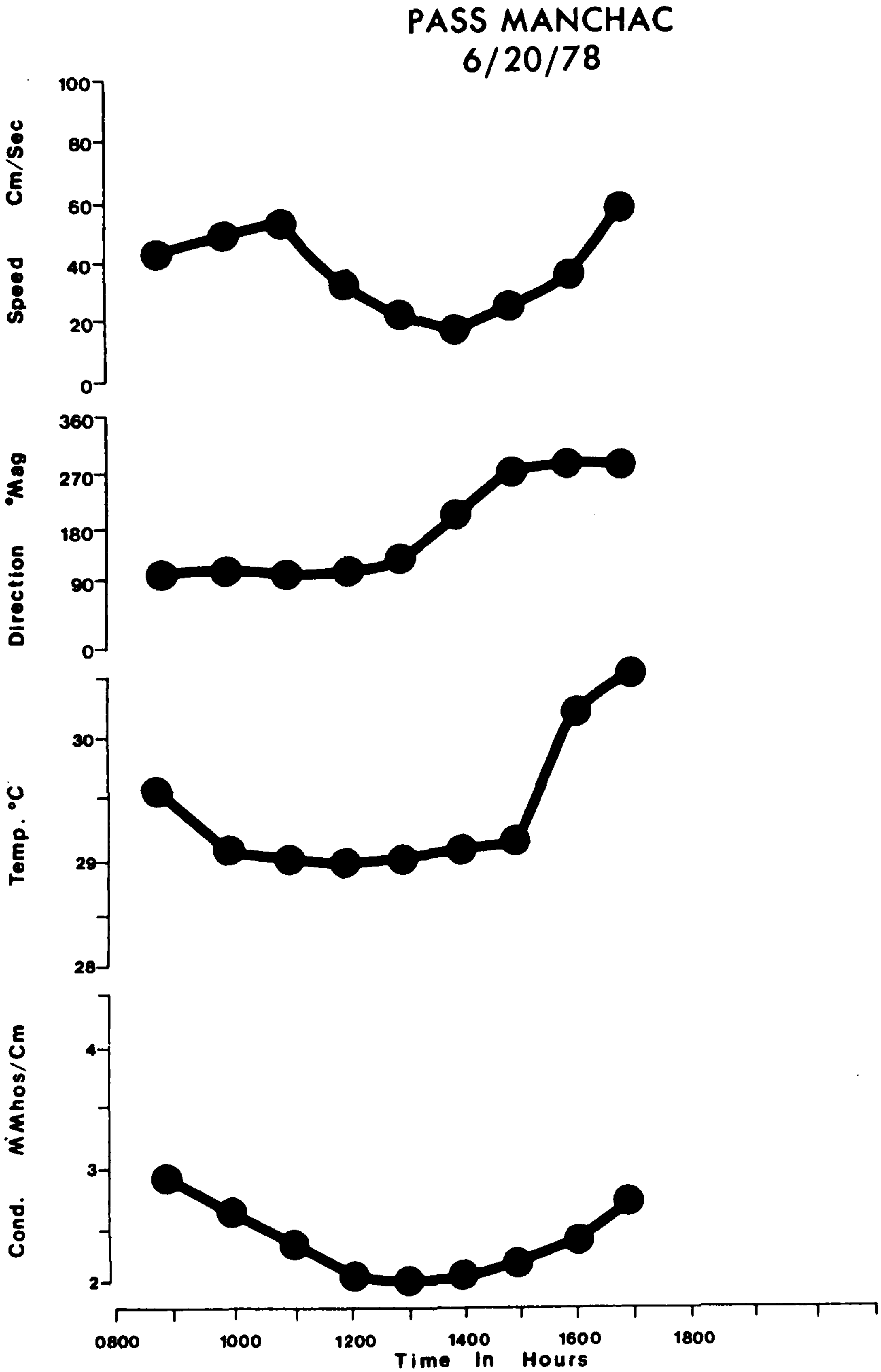


Figure A2-6. Time series plots of (top to bottom): current speed (cm/sec), current direction (°Mag), temperature (°C), and conductivity (mmhos/cm) for Pass Manchac on June 20, 1978. Values are vertical averages.

APPENDIX 3

Measurement of Tidal Transports By Electromagnetic Measurements

ACKNOWLEDGEMENTS

The electromagnetic measurement of tidal transports was made possible through the cooperation of corporations, certain individuals, and an agency. South Central Bell and American Telephone and Telegraph Company (Longlines Division) allowed me the use of the underground cable in the Inner Harbor Navigation Canal. Mr. Pierre Champagne, of South Central Bell, made the arrangements, and Mr. Jesse Fowler, of AT&T, made the electrical hookup. The Louisiana Department of Transportation and Development allowed equipment to be placed on the birdges in the passes. Dr. Wendell S. Brown, at the University of New Hampshire, lent me the electrodes used in the study.

INTRODUCTION

This method depends upon the law of electromagnetic induction (Faraday's Law) and is shown diagrammatically in Figure A3-1. The induced potential (E) is formed by the interaction of the water velocity (V) and the magnetic field of the earth.

The potential (E) produced by the flowing water actually gives a measure of the volume of water flowing through the channel. The volume flow is a useful parameter when conducting a hydrographic study.

The first comprehensive study of this type was an investigation by Wertheim (1959) in the Florida Straits to measure the transport of the Florida current. Wertheim made many simplifying assumptions in his work but was able to demonstrate the feasibility of the method (at least on a large scale).

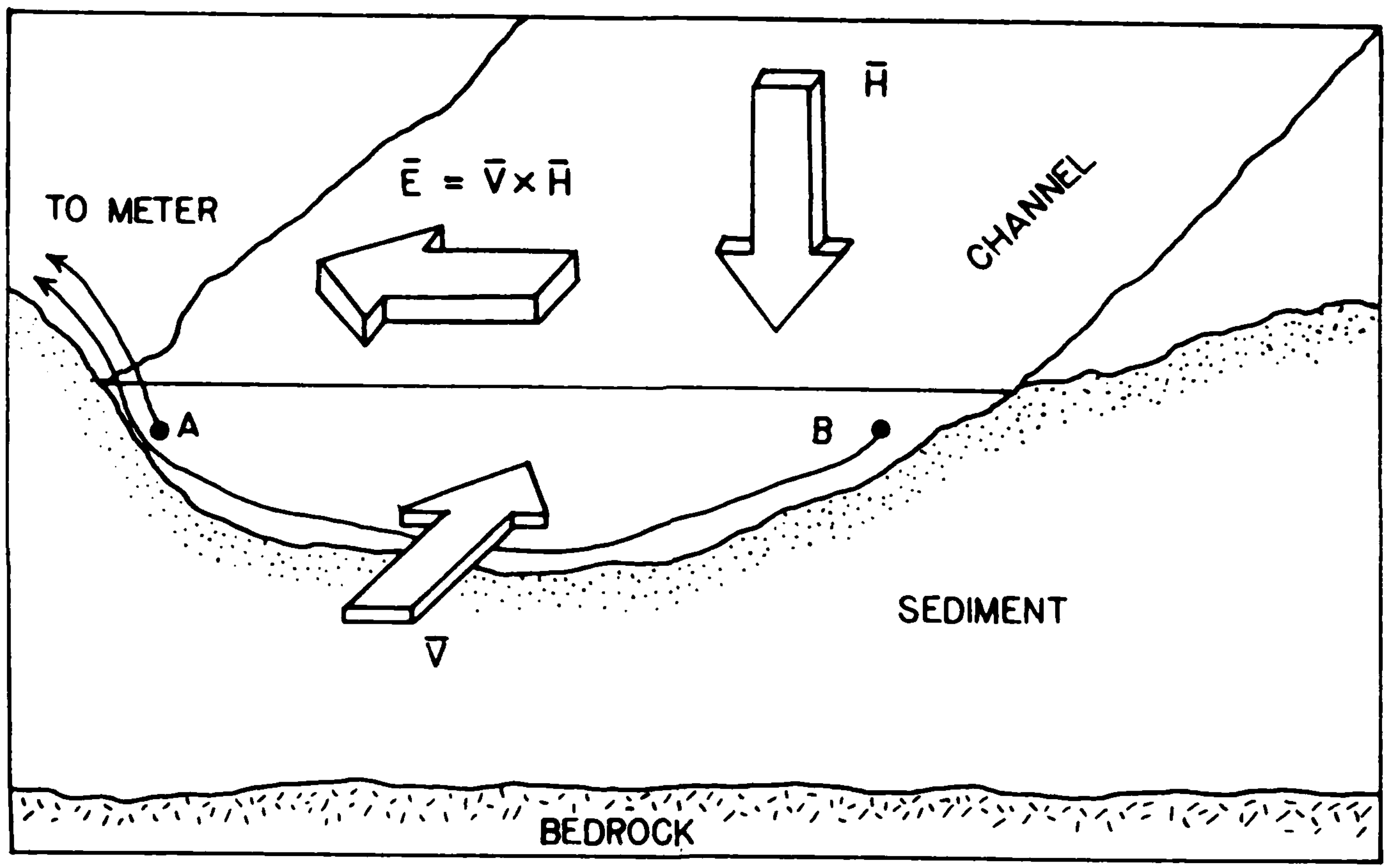


Figure A3-1. Diagram of the electromotive force (E) induced in a tidal channel of width L, by the interaction of the magnetic field of the earth (H) and the velocity (V) of the water. The induced potential is proportional to the vector cross product of V and H, but due to the integrating character of the relation, it is a measure of transport (integrated velocity).

In general, there is no specific relation between the generated potential of a stream and its transport. The potential depends upon the spatial distribution of velocity over the bottom topography and the electrical conductivity of the channel (Sanford and Flick 1975). If transports are to be modelled correctly, all of these factors must be considered. Hence, an empirical calibration to measurments made with a current meter rather than a complete geophysical model is a far simpler procedure. This calibration will allow one to estimate transports from the electrode data.

A layer of conducting sediment will cause attenuation of the induced potential. An equivalent circuit is shown in Figure A3-2. The degree to which the signal is attenuated is a function of seawater conductivity, σ_1 (mmhos/cm); sediment conductivity, σ_2 (mmhos/cm); and the sediment thickness, H_s-H (meters). Sanford (1975) introduces a parameter called BH, whose magnitude is related to EMF attenuation. BH can be calculated from the following relation:

$$BH = \frac{\sigma_1}{\sigma_2(H_s - H)} H$$

Filloux (1974) established that salinity and temperature changes can affect the response of the electrodes. Hence, when making electrode measurements, the salinity and temperature effects must be accounted for.

During 1978, two trial electrode systems were set up in the Lake Pontchartrain system to investigate the feasibility of the method for the system.

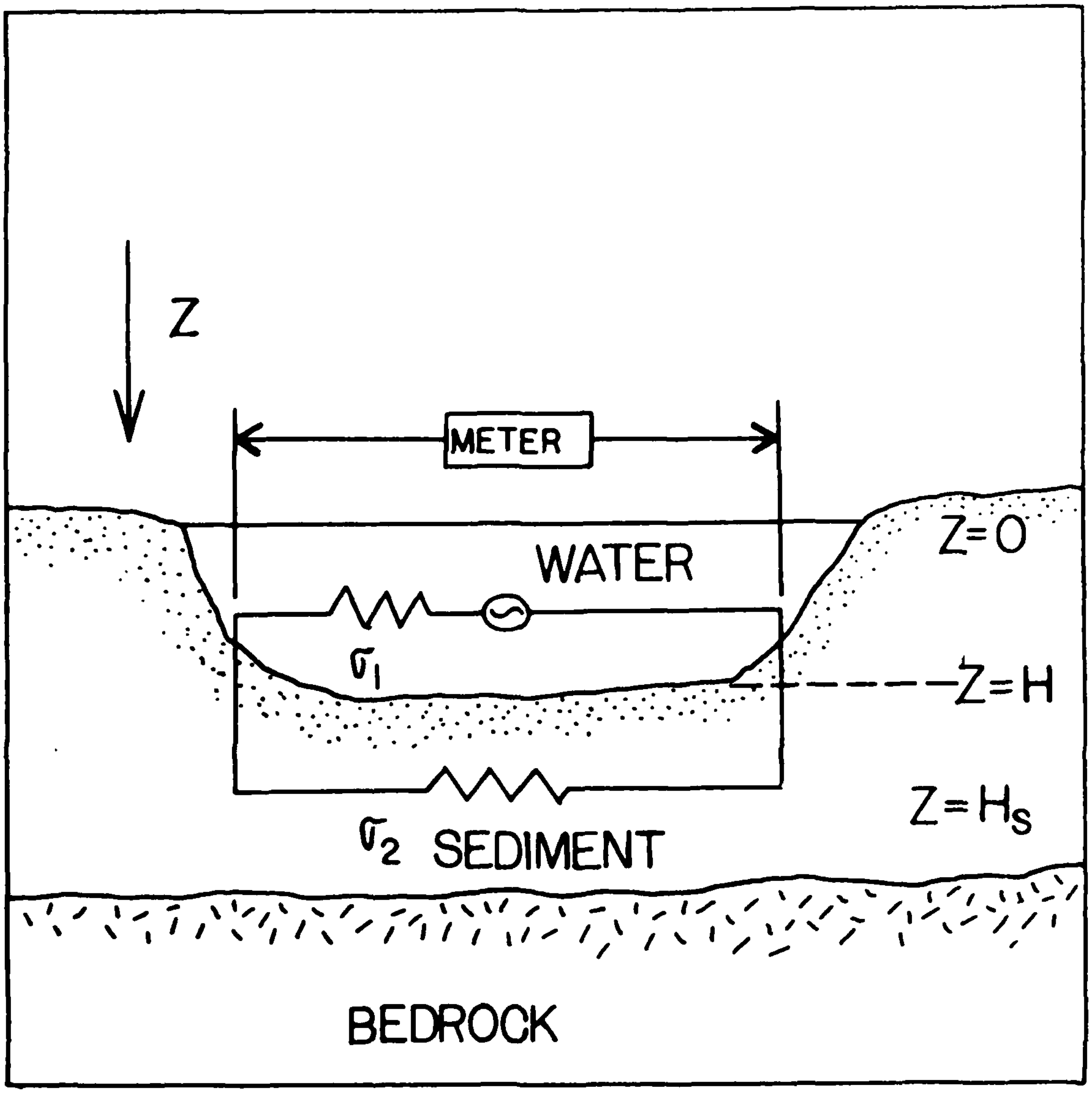


Figure A3-2. An equivalent circuit diagram of the phenomenon described in Figure 19. The circle represents the source of EMF. The current travels through the sediments where the signal is attenuated. The amount of attenuation depends upon: the sediment thickness (H_s-H); the water depth (H); and the ratio of seawater conductivity, σ_1, to the sediment conductivity, σ_2.

MATERIALS AND METHODS

The electrode systems were deployed in the Inner Harbor Navigation Canal (IHNC) at the Highway 90 bridge and in The Rigolets tidal pass at the Highway 90 bridge.

Two electrodes were placed in each pass, one on either side of the strait. The electrodes used were silver-silver chloride (Ag-AgCl), non-polarizing electrodes manufactured by Dr. Jean Filloux at Scripps Institute of Oceanography. A cross section of an electrode is shown in Figure A3-3.

Each electrode was housed in a PVC pipe packed with glass wool to help prevent fouling. The electrodes were fastened to bridge pilings where they would be under water at all times.

In the IHNC, the connection across the channel was made via an underwater telephone cable supplied by South Central Bell and American Telephone and Telegraph.

In The Rigolets, we strung our own cable along the structure of the Highway 90 bridge. The electrodes only covered about half the total distance across the channel and did not go past the bridge turntable. However, the area included about 70% of the channel cross section because of the asymmetry of the channel cross section.

For both deployments the signal was recorded by chart recorders placed on the bridges. See Figure A3-4 for a schematic of the deployment configuration.

During a 24-hour study in the Chef Menteur Pass, an electrode system was deployed in order to have simultaneous water current speeds and electric potential measurements.

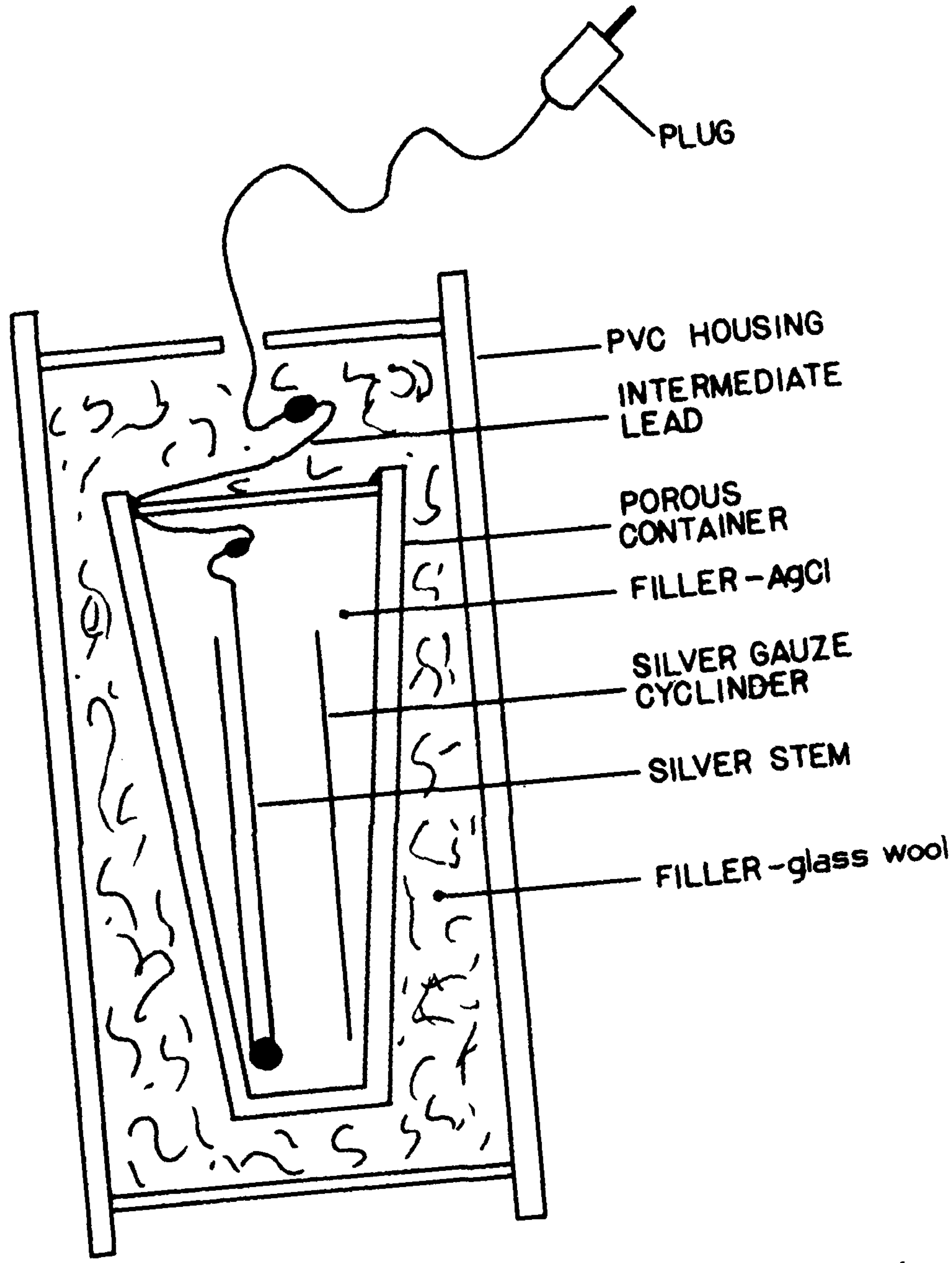
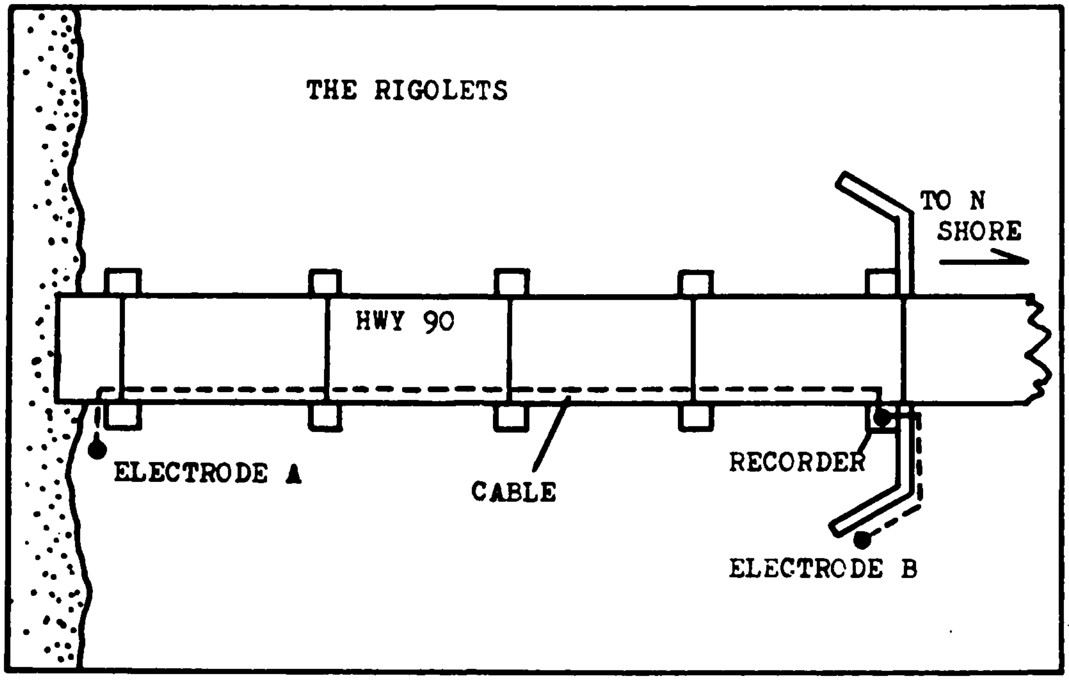


Figure A3-3. A cross section of the electrode type used in the study. The electrodes were made by Dr. Jean Filloux at Scripps Institute of Oceanography. Diagram from Filloux 1974.



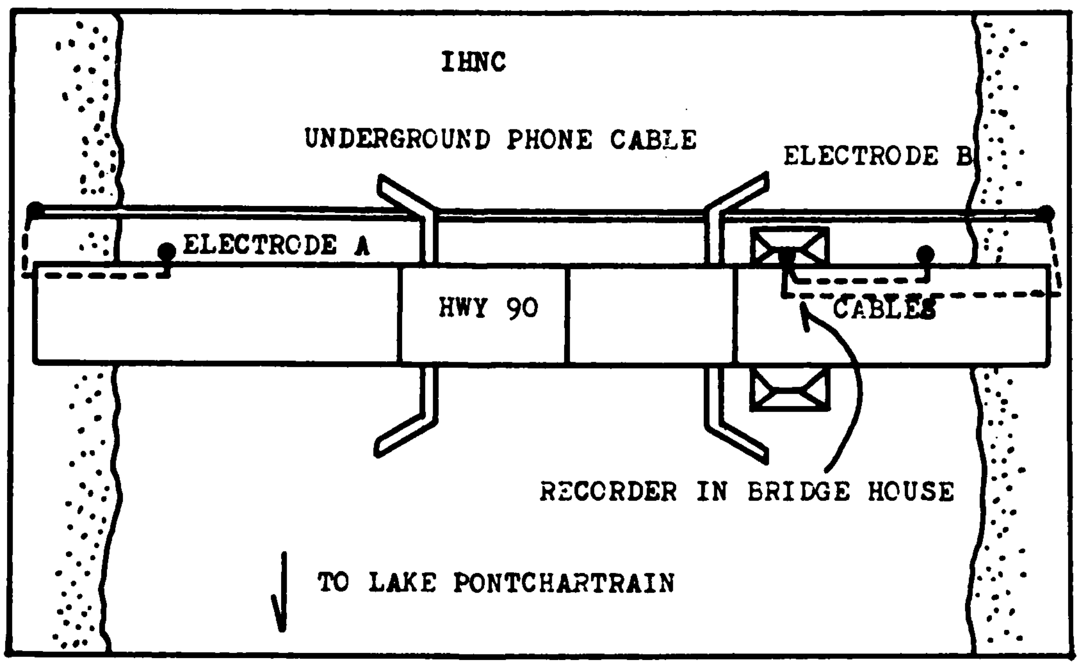


Figure A3-4. Schematic diagram of the deployment configuration used during the study. See text for explanation.

RESULTS

Figure A3-5 shows the data collected in the calibration study in the Chef Menteur Pass. There is excellent agreement between the current speeds and the electric potential.

Figure A3-6 shows time series of electric potential data collected in The Rigolets and the IHNC. The electric potential data do appear to show a pattern indicative of tidal flow. Using these data, the current data collected in the passes (from this study), and data on sediments from the Louisiana Geologic Survey (Cardwell et al. [1967]), the expected potential based upon Sanford's (1975) model was calculated. The results are presented in Table A3-1. It can be seen that, in general, the expected signal is in agreement with the actual measured signal.

SUMMARY

The data collected during this feasibility study indicate that the method can be used with success in the tidal passes of Lake Pontchartrain. However, this study was only a first attempt, and the method needs to be refined if it is to be used on a regular basis in Lake Pontchartrain. Improvements should include:

1) The installation of a separate cable for the system (the phone cable is too noisy), preferably a heavy duty underwater cable.
2) A method of recording the data should be used that is more adequate than chart recorders.
3) The salinity and temperature effects on the calibration need to be better defined. The changes in seawater conductivity over a tidal cycle will affect the calibration.
4) Some sort of calibration procedure (using current meters) will have to be conducted on a periodic schedule.

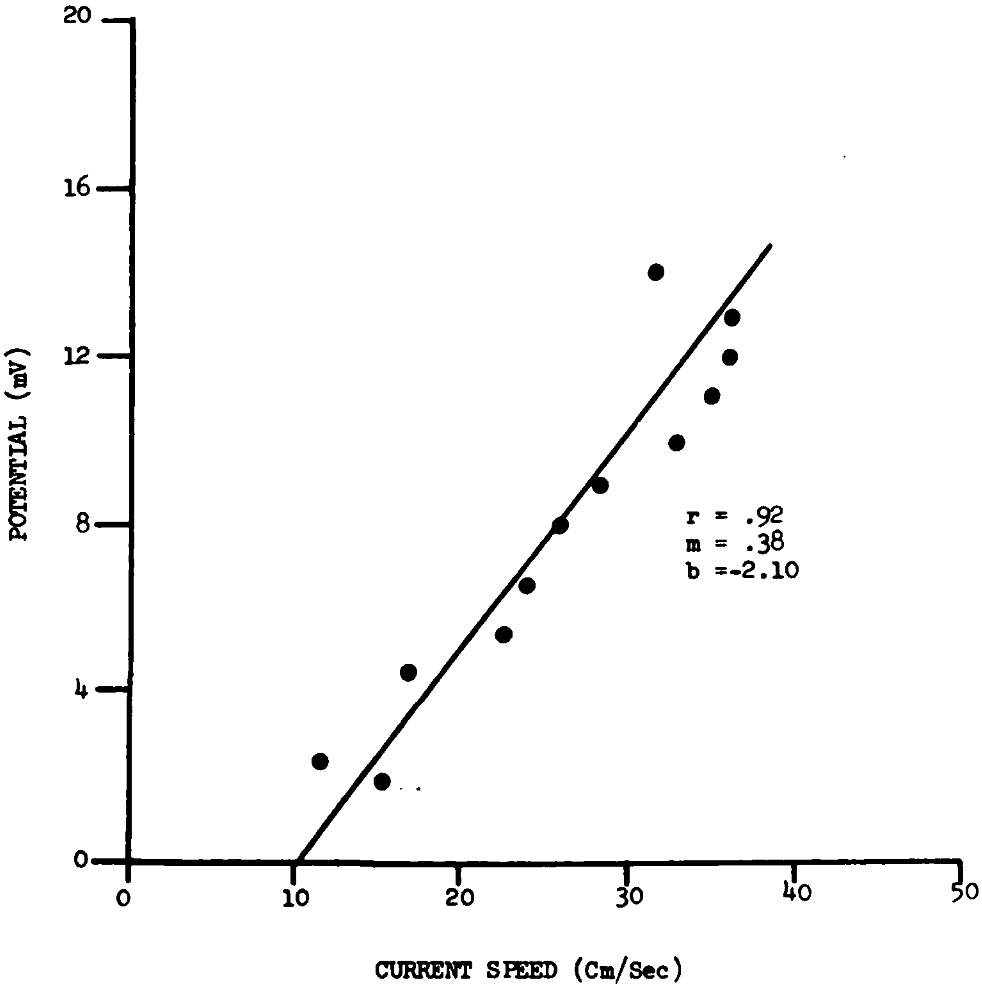


Figure A3-5. Plot of induced electric potential versus current speed. Data from Chef Menteur Pass, July 11, 1978. The results of a regression analysis are indicated.

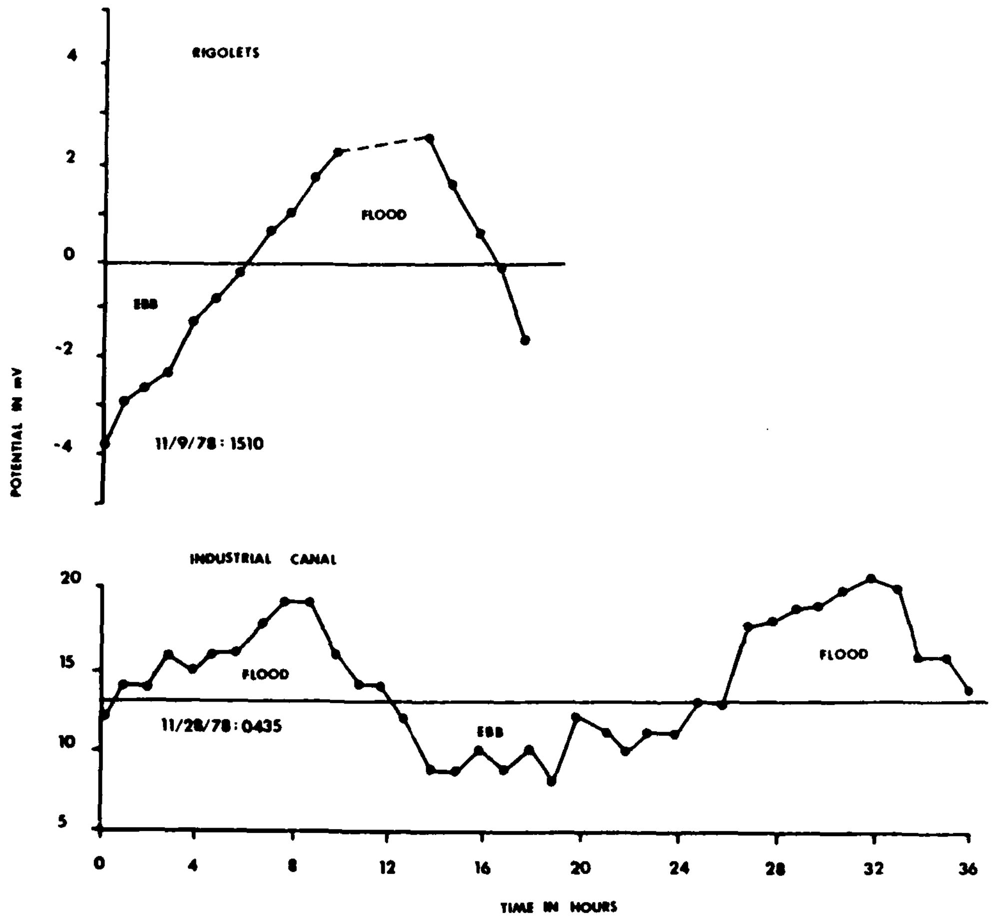


Figure A3-6. Time series of electric potential data from The Rigolets tidal pass (top) and the Inner Harbor Navigation Canal (IHNC) (bottom). The starting date and time of each series are indicated near the origin of each plot.

Table A3-1. Estimate of Expected Electrical Signal for Tidal Passes of Lake Pontchartrain, LA

Electrical potential is given by (Sanford 1975):

$$\Delta\phi = BH \left[\frac{F_z UL}{1 + BH}\right]$$

where:

$\Delta\phi$ = potential (volts)
H = water depth (m)
F_z = earth's magnetic field (webers)
V = current speed (m/sec)
L = channel width (m)
BH = sediment attenuation factor

$$BH = \frac{\sigma_1}{\sigma_2} \quad \frac{H}{H_s - H}$$

σ_1 = Water conductivity (mmhos/cm)
σ_2 = Sediment conductivity (mmhos/cm)
$\frac{H}{H_s - H}$ = Sediment thickness (m)

A) Inner Habor Navigation Canal (IHNC)

$H \sim 10$
$L \sim 100$
$U \sim .60$
$BH \sim 24$
$F_z = .46 \times 10^{-4}$

$$\Delta\phi = 24 \left(\frac{(.47 \times 10^{-4})\ (.6)\ (100)}{1 + 24}\right) \sim 3.0 \text{ mV}$$

Data shows signal of $\sim$ 6.0 mV

B) The Rigolets

$H \sim 10$
$L \sim 350$
$U \sim .50$
$BH \sim 24$
$F_z = .47 \times 10^{-4}$

$$\Delta\phi \quad 24 \left(\frac{(.47 \times 10^{-4})\ (.5)\ (350)}{1 + 24}\right) \sim 8 \text{ mV}$$

Data shows signal of $\sim$ 5 mV

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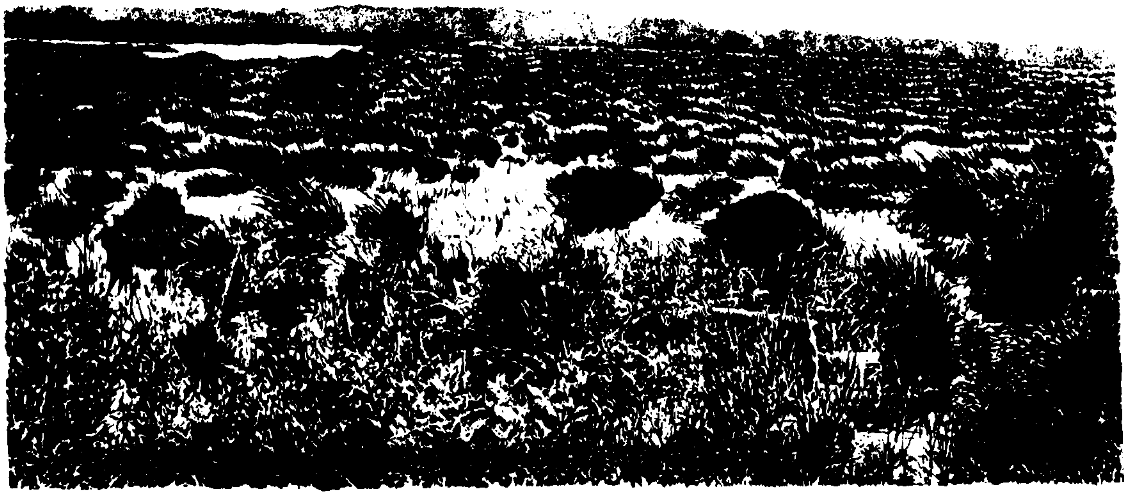

Marsh near Mandeville

Chapter 6

NUTRIENT AND CARBON GEOCHEMISTRY IN LAKE PONTCHARTRAIN, LOUISIANA

by

Ronald K. Stoessell

ABSTRACT

Conductivities and concentrations of organic and inorganic nutrient and Carbon (C) fractions in Lake Pontchartrain in 1978 are reported as a function of location, depth, and time of year. These data were used to describe lakewide chemical variations and to define seasonal trends. Significant chemical gradients with depth occurred only at the mouth of the Inner Harbor Navigation Canal (IHNC) where a salt wedge commonly exists. Seasonal trends were fairly consistent throughout the lake except for the area bordering the southern shoreline, which was probably being contaminated by New Orleans' waste waters.

Maximum concentrations of inorganic nutrients, organic C fractions, and dissolved Phosphorus (P) usually occurred during the spring; minimum concentrations occurred during the summer. Levels of the inorganic Nitrogen (N) fractions and undissolved organic C commonly remained low during the fall. However, concentrations of Phosphate (PO_4^{3-}), Silicate (Si), dissolved organic C, and dissolved P tended to increase in the fall. Higher than average concentrations of PO_4^{3-} and dissolved P occurred on the south side of the lake. Inorganic C contents increased spatially from west to east and southeast across the lake.

High concentrations in the spring for inorganic nutrients, dissolved P, and the organic C fractions could be related to maximum river input and to stream flooding through adjacent swamps and marshes into the lake. Assimilation of inorganic nutrients by organisms could explain their low concentrations in the summer. Increased levels of Si in the fall may result from the death and dissolution of diatoms. Higher PO_4^{3-} and dissolved P contents in the fall are probably due to nutrient release from suspended sediment in the water column. Continued low values of inorganic N fractions in the fall imply N is growth limiting for some lake organisms.

INTRODUCTION

The nutrient and carbon geochemistry in Lake Pontchartrain reflects organic and inorganic reactions together with input sources and output sinks. How the concentrations of the nutrient and carbon components affect the biomass cannot be determined until their spatial and time distributions are known. Then the lake can be modelled numerically to reproduce the observed distributions using appropriate reaction rates together with sources and sinks such as: river water input, exchange of brackish water with Lake Borgne, freshwater input from Lake Maurepas, component fluxes in and out of lake bottom sediments, and atmosphere exchange processes. By varying the magnitudes of the reaction rates together with the sources and sinks, the ecological controls can be quantitatively determined.

The present report has two major objectives. The first is to provide good chemical data together with reliable precision estimates for nutrient and carbon fractions in Lake Pontchartrain. Earlier reported

data (Stern et al. 1968) are of limited use because test kits were used instead of established laboratory methods. The second objective is to describe the seasonal variations of the spatial distributions of the nutrient and carbon fractions. Qualitative conclusions are drawn relating these distributions to the lake's ecological system as well as to inorganic reactions, freshwater input, exchange of brackish water, and component fluxes between the lake and the bottom sediments.

MATERIALS AND METHODS

I. Field Methods

Water samples for chemical analyses were collected in Lake Pontchartrain and adjacent areas at the locations shown in Figure 1. Samples within the lake were taken as a function of depth on a monthly to quarterly and sometimes semiannual basis in 1978 and early 1979. One set of samples was collected throughout the lake at 14 survey stations, 4 master stations, and a number of experimental stations (Dow and Turner, Chapter 7). A second set was collected near Goose Point, Irish Bayou, New Orleans East, and Walker Canal (Cramer and Day, Chapter 9); and a third set was taken off Goose Point (Miller 1980).

Samples reported on in this study are from the survey (S) and master (MS) stations within Lake Pontchartrain. The field and laboratory procedures are illustrated schematically in Figure 2. The bottles used for storage of aliquots in the field had been washed with chromic acid and rinsed with distilled-deionized water. Sample depths are accurate to the nearest 0.20 meters after making allowances for wave heights. Field pH measurements were made using Orion model 407A or 701 pH meters, which were calibrated daily in the field with pH 4 and 7 buffers.

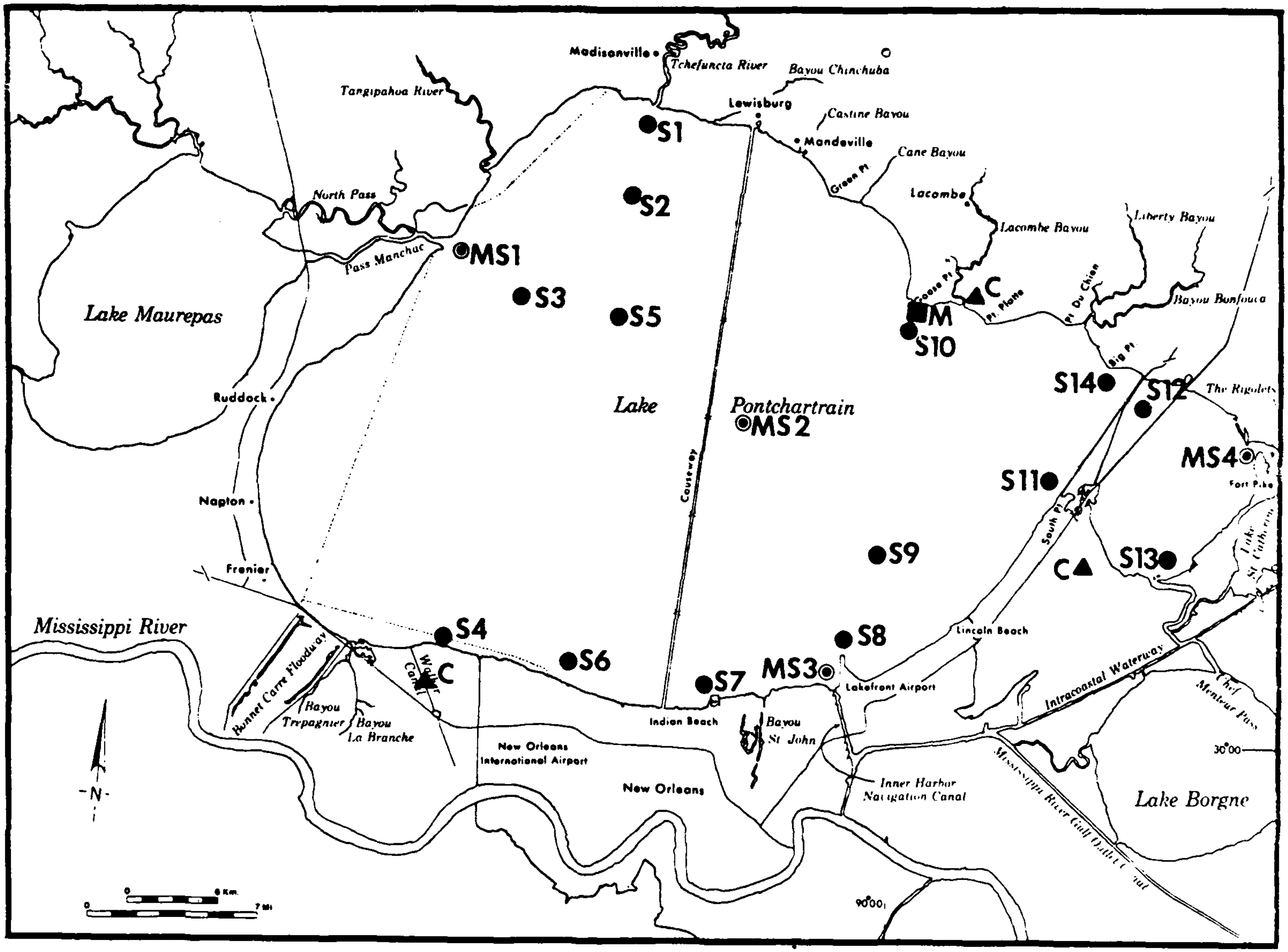

Figure 1. Sample site locations within Lake Pontchartrain and the adjacent area. S1-S14 and MS1-MS4 sites are from Dow and Turner (Chapter 7); C sites are from Cramer and Day (Chapter 9); and the M site is from Miller (1980).

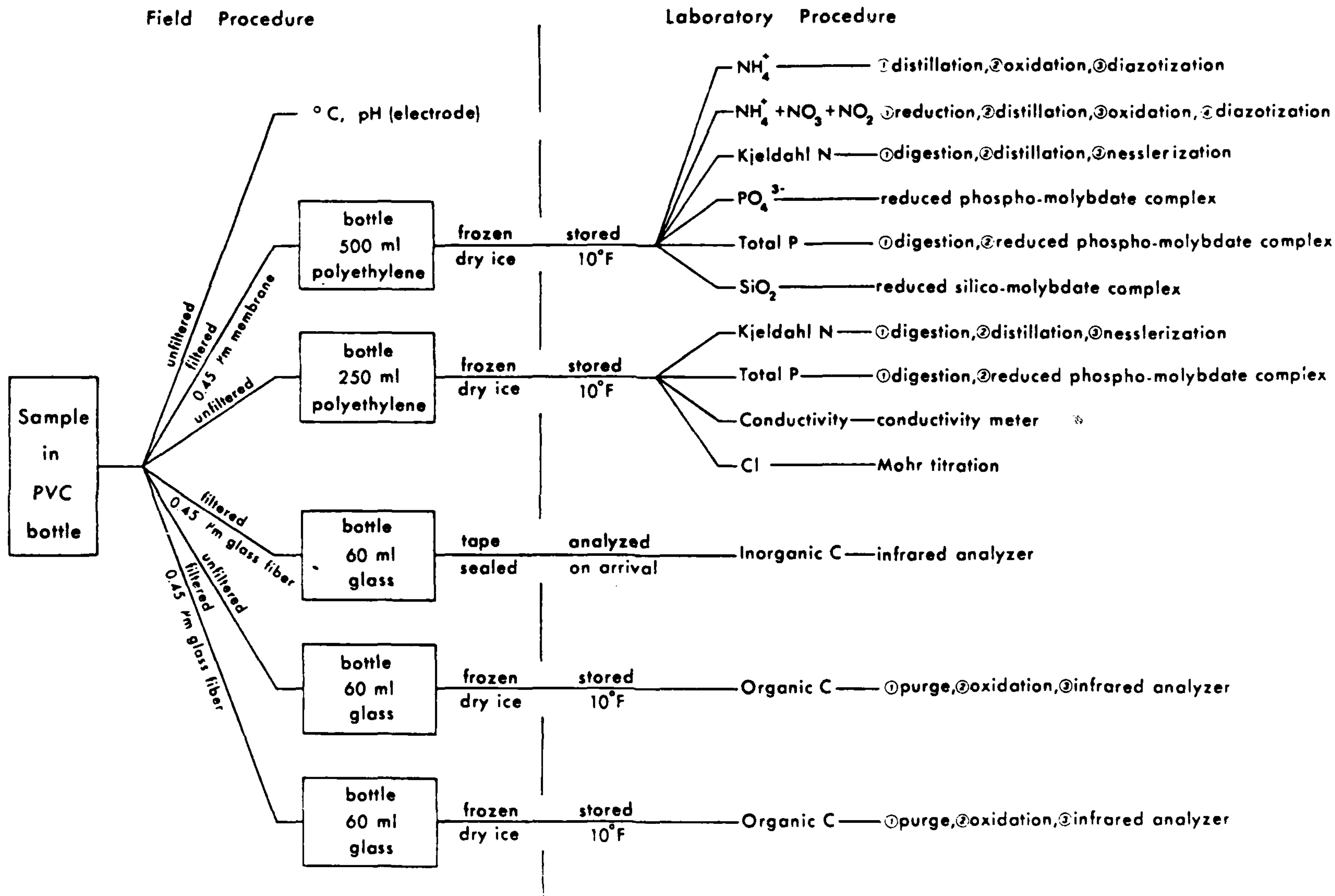

Figure 2. A schematic diagram of the field and laboratory procedures followed in this study.

II. Analytical Methods

The chemical constituents shown in Figure 2 represent the maximum number analyzed within a sample. The analytical methods used for these constituents are discussed below. The terms "dissolved" and "total" refer to whether the analyses were made on filtered (0.45 μm) or unfiltered aliquots, respectively. The difference between the total and dissolved concentrations of a constituent is called the "undissolved" fraction in this report. A detailed, step-by-step listing of the methods used in this study is given by Byrne et al. (1979), an unpublished laboratory manual included in the Appendix.

A. Nitrogen Fractions

The analyzed N fractions include dissolved ammonia and ammonium (NH_3 + NH_4^+), dissolved inorganic nitrogen (NH_3 + NH_4^+ + NO_3^- + NO_2^-), and dissolved and total Kjeldahl N (organic N + NH_4^+ + NH_3). The methods for nitrogen used in this study are those described by Ho and Barrett (1975) that were modified from Strickland and Parsons (1965). Minor modifications of Ho's methods include the acid washing of all glassware in 0.4 N HCl and the cleaning of the still between samples by distilling for three minutes and for one minute successive aliquots of 0.4 N HCl and distilled water, respectively.

NH_3 + NH_4^+: A filtered water sample is made basic with MgO to convert NH_4^+ to NH_3 and the solution is steam distilled into 0.1 N HCl. The collected NH_4^+ is oxidized to NO_2^- by an alkaline KBr chlorox solution and the excess oxidizing agent is poisoned with sodium arsenite after 0.5 hours. The nitrite is added to sulfanilamide and diazotized with napthyl ethylenediamine dihydrochloride. This forms a highly colored azo dye that is measured colorimetrically.

$NH_3 + NH_4^+ + NO_2^- + NO_3^-$: A filtered water sample is made basic with MgO, and oxidized forms of N are reduced with Devarda alloy, converting all inorganic forms of N to the distillable form NH_3. The procedure then follows that described above for NH_4^+.

Kjeldahl N (dissolved and total organic N + NH_4^+ + NH_3): A filtered or unfiltered (for dissolved or total measurement) water sample is digested with sulfuric acid and a Kjeldahl catalyst ($K_2SO_4/CuSO_4/Se$) for one hour at 370°C (following water evaporation at 140°C). This converts organic N to NH_4^+. The solution is made basic with 10 N NaOH to convert NH_4^+ to NH_3, and then NH_3 is steam distilled into 0.1 N HCl. The collected NH_4^+ is nesslerized to form the colored complex $Hg(NH_2)I$, which is measured colorimetrically.

B. <u>Phosphorus Fractions</u>

The P fractions analyzed include dissolved inorganic phosphate (PO_4^{3-}) and dissolved and total phosphorus. The method for dissolved inorganic phosphate used in this study is that described by Ho and Barrett (1975), which was modified from Strickland and Parsons (1965). Dissolved and total phosphorus were measured by the persulfate digestion method in Standard Methods (Am. Public Health Assoc. 1976). A minor modification made on these methods was to store the separatory funnels in 1% H_2SO_4 after acid cleaning.

PO_4^{3-}: An acidified filtered water sample is treated with an ammonium molybdate solution that converts the PO_4^{3-} fraction to a phosphomolybdate complex that is extracted with ethylacetate. This complex is reduced with ascorbic acid in the presence of an antimonyl

potassium tartrate solution, resulting in the formation of a highly colored antimonyl-phosphomolybdous complex, which is measured colorimetrically.

Phosphorus (dissolved and total): An acidified filtered or unfiltered (for dissolved or total measurement) water sample is digested in a potassium persulfate solution for 1/2 hour at 90°C to release the oxidizable organic phosphorus as inorganic phosphate. The PO_4^{3-} is then determined as described above for PO_4^{3-}.

C. <u>Silicate</u>

The procedure of Strickland and Parsons (1965) is used to determine dissolved Si. There is a significant adsorption of silica on the walls of the polyethylene storage bottles that have been frozen. Upon defrosting, aqueous Si concentrations increase by a factor of 2 or 3 between 1-5 days after defrosting. Additional amounts of time have no significant effect.

A filtered sample that had been defrosted for a minimum of five days is mixed with an acidic ammonium molybdate solution to produce a silicomolybdate complex. Oxalic acid is added to destroy any phosphomolybdate complex present. The silicomolybdate complex is then reduced with a metol sulfite solution to form an intensely colored silicomolybdous complex, which is measured colorimetrically.

D. <u>Carbon Fractions</u>

The analyzed C fractions include total inorganic carbon (TIC), total organic carbon (TOC), and dissolved organic carbon (DOC). These fractions are measured on a multicomponent analyzer system, "The Total Carbon System" manufactured by Oceanography International Corporation (OIC).

The components consist of a purging module, a Horiba Model PIR-2000 non-dispersive infrared analyzer, and an integrator. The methods used in this study are those given by OIC (1978) in the instruction and procedure manual of the model 0524B.

TIC: A filtered water sample is injected directly into a strong mineral acid solution. The solution is purged with nitrogen, and the released CO_2 is measured on an infrared analyzer. Each reported analysis is the average of two determinations.

TOC and DOC: Potassium persulfate is added to a precombusted ampule and is followed by the addition of an aliquot of an unfiltered or filtered (TOC or DOC measurement) water sample. The solution is made up to 5 ml with distilled-deionized water, and 0.25 ml of phosphoric acid is added. The solution is purged of inorganic carbon with oxygen and the ampule is sealed. Oxidation of organic carbon to CO_2 takes place by heating the ampule in a pressure vessel for 24 hours at 175°C or by heating in an autoclave at 120°C and 16 psi for 2 hours. The ampule is then broken, the CO_2 is released by nitrogen purging, and it is subsequently measured on the infrared analyzer. Each reported analysis is the average of 4 determinations.

E. Conductivity and Chlorosity

An unfiltered sample is used in the determination of both conductivity and chlorinity. Conductivity is measured on a Lab-Line Lectro MHO meter model MC-1, Mark IV. Chlorosity is determined using a Mohr titration. The titrant is a silver nitrate solution and the indicator is potassium chromate (Am. Public Health Assoc. 1976).

III. Field and Laboratory Precision

The overall precision of a reported analysis is a function of the precision of the field and laboratory procedures, which include sampling, shipboard techniques, field storage, laboratory storage, and the analytical method. To establish precision data on the measured nutrient concentrations, i.e., for the analyzed fractions of nitrogen, phosphorus, and silica, a series of triplicate replicates were taken at the four master stations during the summer of 1978. These sets of replicates were taken as a function of depth and time of day.

A sample population of standard deviations was computed for each of the analyzed nutrient fractions using the sets of replicates. The analyzed data used to compute the standard deviations were taken from Table A1. The average standard deviation for each sample population is an estimate of the overall precision (excluding sampling errors). These average standard deviations and their coefficients of variation are listed in Table 1.

Similar data are also listed in Table 1 for precision estimates on the analytical methods. These estimates were obtained from sets of duplicate replicates where each set was taken from a single bottle in the laboratory. It should be noted that for both the replicate sets from the field and the replicate sets in the laboratory, the analyses (for a particular nutrient fraction) from within a replicate set were not done in the same batch and, in general, were made by different analysts using different standards.

As stated above, the mean standard deviations listed in Table 1 can be considered overall precision estimates resulting from the shipboard techniques, field and laboratory storage, and the analytical methods.

Table 1. Statistical Data for Precision Estimates

Anal.[a]	Triplicate field replicates[b]			Duplicate lab. replicates[c]		
	Mean s.d. ug-at E/1	C.V. %	Sets of data	Mean s.d. ug-at E/1	C.V. %	Sets of data
NH_4	1.5	78	22	0.2	75	4
TIN	2.4	104	22	1.1	65	4
K_D	4.4	76	21	2.6	102	7
K_T	6.2	64	23	1.4	89	4
PO_4^3	0.26	78	20	0.02	112	22
TDP	0.32	104	15	0.09	55	7
TP	0.34	126	23	0.05	80	7
Si	11.7	90	8	0.5	124	12
DOC	60	78	4			
TOC	30	67	3			
TIC	70	77	5			
Cl^-				0.01 g/l	81	19
Cond.	0.4 $\frac{\text{mmhos}}{\text{cm}}$	160	23	0.2 $\frac{\text{mmhos}}{\text{cm}}$	92	13[d]

[a] $NH_4 = NH_3 + NH_4^+$; TIN = $NH_3 + NH_4^+ + NO_2^- + NO_3^-$; K_D = dissolved Kjeldahl N; K_T = total Kjeldahl N; PO_4^{3-} = dissolved PO_4^{3-}; TDP = total dissolved phosphorus; TP = total phosphorus; Si = dissolved reactive Si.

[b] Each replicate set was taken in the field from a single bottle.

[c] Each replicate set was taken in the laboratory from a single bottle.

[d] Eight sets of triplicate replicates and five sets of duplicate replicates.

For the nutrient fractions, the mean standard deviations range from a factor just under 2 up to 25 times that of the corresponding mean standard deviations for the analytical methods listed in Table 1. Apparently, contributions to the estimated precisions from the analytical methods are generally minor compared to variations resulting from shipboard techniques and the field and laboratory storage. This is particularly true for Si because of the adsorption effect, discussed earlier, during storage. In addition, there are problems, as yet unresolved, of changes in concentrations of the various nitrogen and phosphorus fractions resulting from filtration and storage (Ho and Barrett 1975).

Table 1 contains additional statistical data for the analyzed fractions of carbon, chlorosity, and conductivity. With the exception of chlorosity, these data are complete for precision estimates for the field methods. As shown in Table A1, not enough of the individual replicates from the sets of field triplicates were analyzed for chlorosity to compute an average standard deviation. Statistical data on the analytical methods for carbon fractions were not compiled because the reported data are averaged values from multiple determinations.

Analyses of variance were made using the nutrient and conductivity data from the same sets of field triplicate replicates used to determine the mean standard deviations discussed above (Table A1). At each master station, sets were taken at three different depths at two different times of day. Under conditions stated below, differences between mean values of a component were tested to see if they were greater than would be expected due to chance alone. In this discussion, "chance" refers to the variation in the sample values due to differences resulting from the sampling method, shipboard handling, field storage, laboratory storage,

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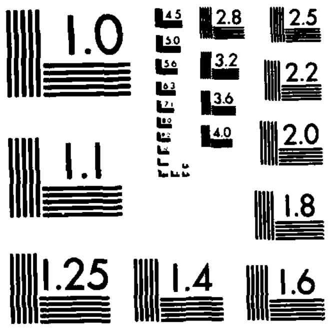

MICROCOPY RESOLUTION TEST CHART
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and the analytical method. For each station at a particular time, a one-way analysis of variance was used to test differences between mean values of a component of different depths. A two-way analysis of variance was used to test differences in the value of a component averaged for the water column at different times of day and averaged for a day at different depths. For shallow depths (less than four meters), the null hypothesis that differences between mean values were due to chance (α=.05) was accepted for different depths and different times of day at a station. This was true for the nutrient fractions and the conductivity at each of the master stations. These statistics were used to justify averaging such data to look for seasonal variations.

RESULTS

Chemical data from the survey and master stations are listed in the Appendix in Table A1. These data are reported in fractions that have been computed from the analyzed components, as described in the Appendix. Depth and time averaged values together with 95% confidence intervals are given in Table A2.

A total average value for each of the nutrient fractions can be computed from all the data in Table A1. These averages can then be compared with the corresponding overall precision estimates shown in the heading of Table A1. The overall precision estimates range from 20 to 90% of the corresponding total average values. Some of the precision errors are probably overestimated, as discussed in the Appendix, and a more realistic range is 20 to 50%. Consequently, subtle chemical trends are not going to be recognized in the data from this study. This study delineates seasonal trends at the various stations and detects

differences with depth at Master Station 3 where a salt wedge generally exists.

As shown in Table A2, adequate chemical data to establish seasonal trends are only available at certain stations. These include Survey Stations 1, 2, 3, 5, and 7 and Master Stations 1, 2, 3, and 4. The scattered data available at the other stations will be used to clarify these trends.

I. Northwest Lake Pontchartrain

Survey Stations 1, 2, 3, and 5 together with Master Station 1 are located within the northwest quarter of the lake (Fig. 1). The major nutrient inputs into this area are probably due to the influx of fresh waters from the Tchefuncte and Tangipahoa Rivers and from Lake Maurepas by way of North Pass and Pass Manchac. The waters are characterized by low salinities compared to the rest of Lake Pontchartrain.

The available averaged nutrient data for shallow waters from Table A2 are plotted versus time of year on Figures 3-7 for Survey Stations 1, 2, 3, and 5 and Master Station 1, respectively. A similar plot for deeper waters at Master Station 1 is shown on Figure 8.

Nutrient concentrations (μg-at element l^{-1}) in the northwest quarter of the lake had the following ranges (Table A2): dissolved P, 0.16-2.25; undissolved P, 0.00-3.84; PO_4^{3-}, 0.22 -1.51; Si, 7-106; NH_3 + NH_4^+, 0.0-9.6; NO_2^- + NO_3^-, 0.0-23.5; dissolved organic N, 20.7-34.5; and undissolved organic N, 0.0-13.4.

In general, the seasonal trends showed yearly minimum values in the summer for Si, dissolved P (which is predominantly PO_4^{3-}), PO_4^{3-}, and in the summer and fall, for NH_3 + NH_4^+ and NO_2^- + NO_3^-. Yearly maximum values usually occurred in later winter and spring for all the nutrient fractions.

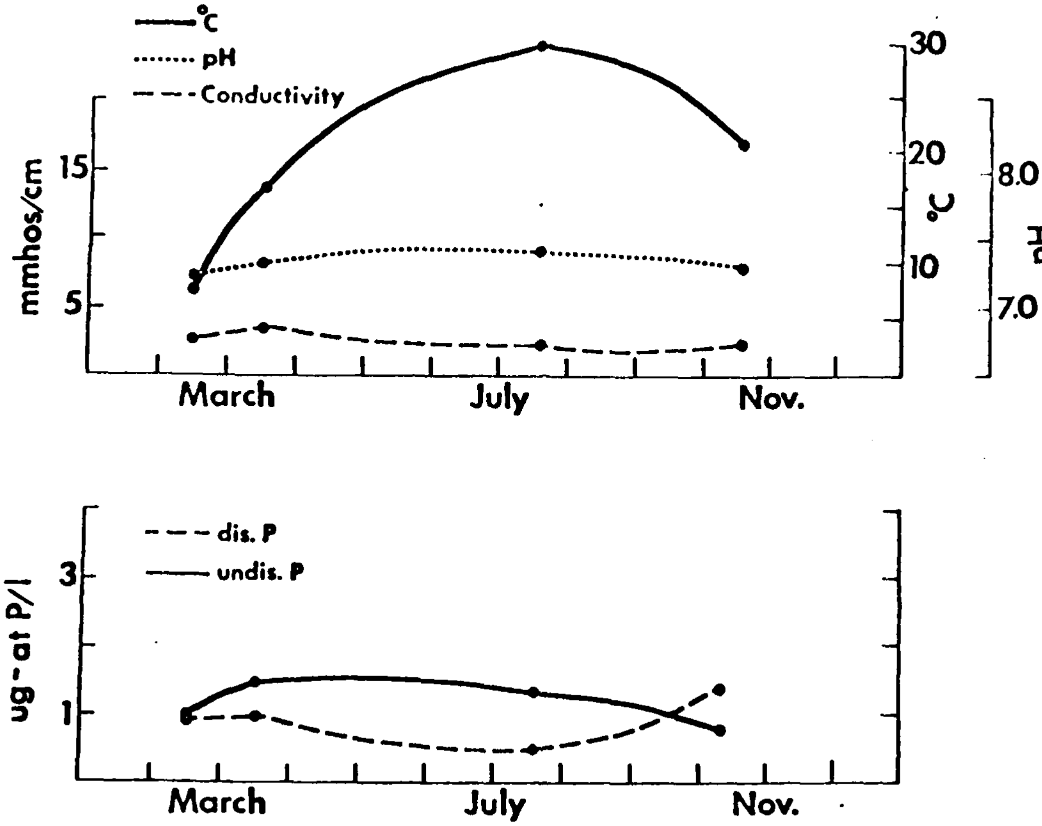
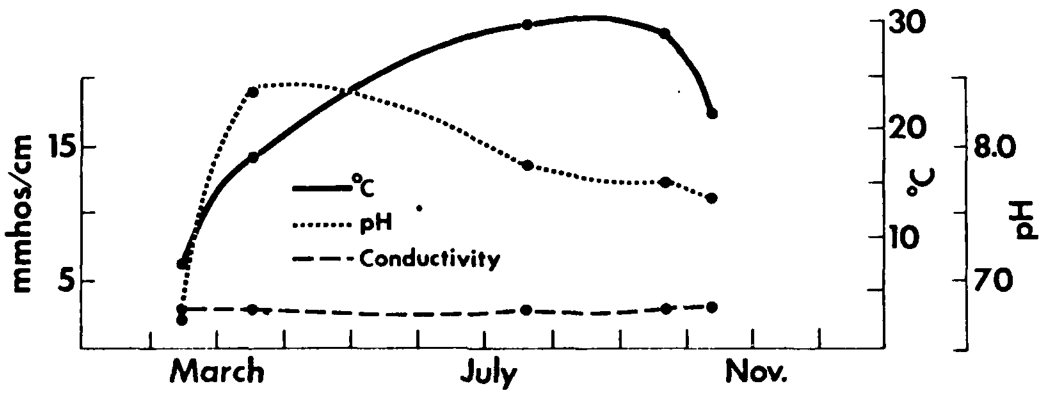


Figure 3. Depth and time averaged chemical data (Table A2) for shallow waters (0-2.5 m) at Survey Station 1 in Lake Pontchartrain, LA, during 1978.



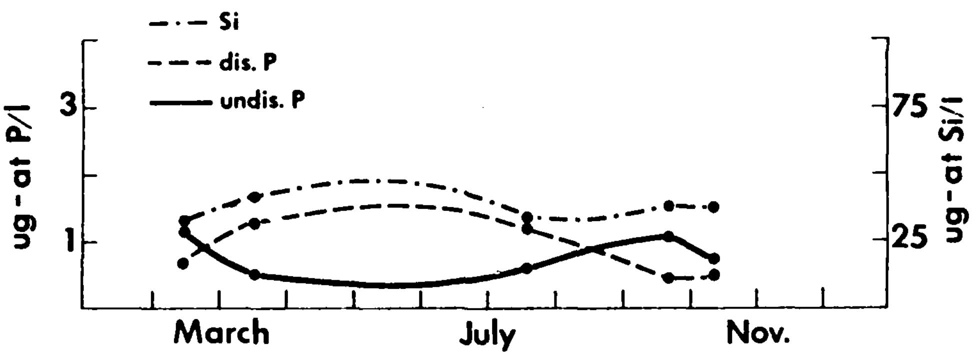


Figure 4. Depth and time averaged chemical data (Table A2) for shallow waters (0-3 m) at Survey Station 2 in Lake Pontchartrain, LA, during 1978.

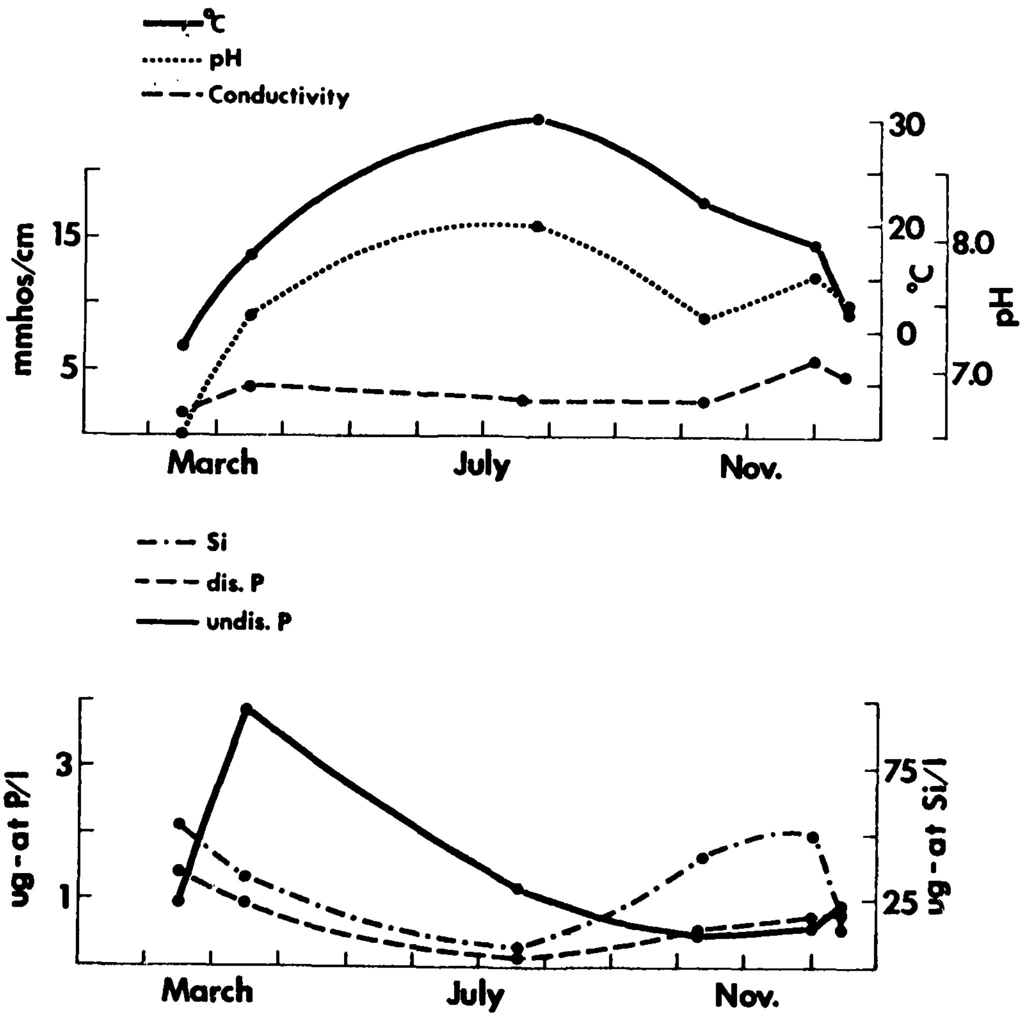


Figure 5. Depth and time averaged chemical data (Table A2) for shallow waters (0-3 m) at Survey Station 3 in Lake Pontchartrain, LA during 1978.

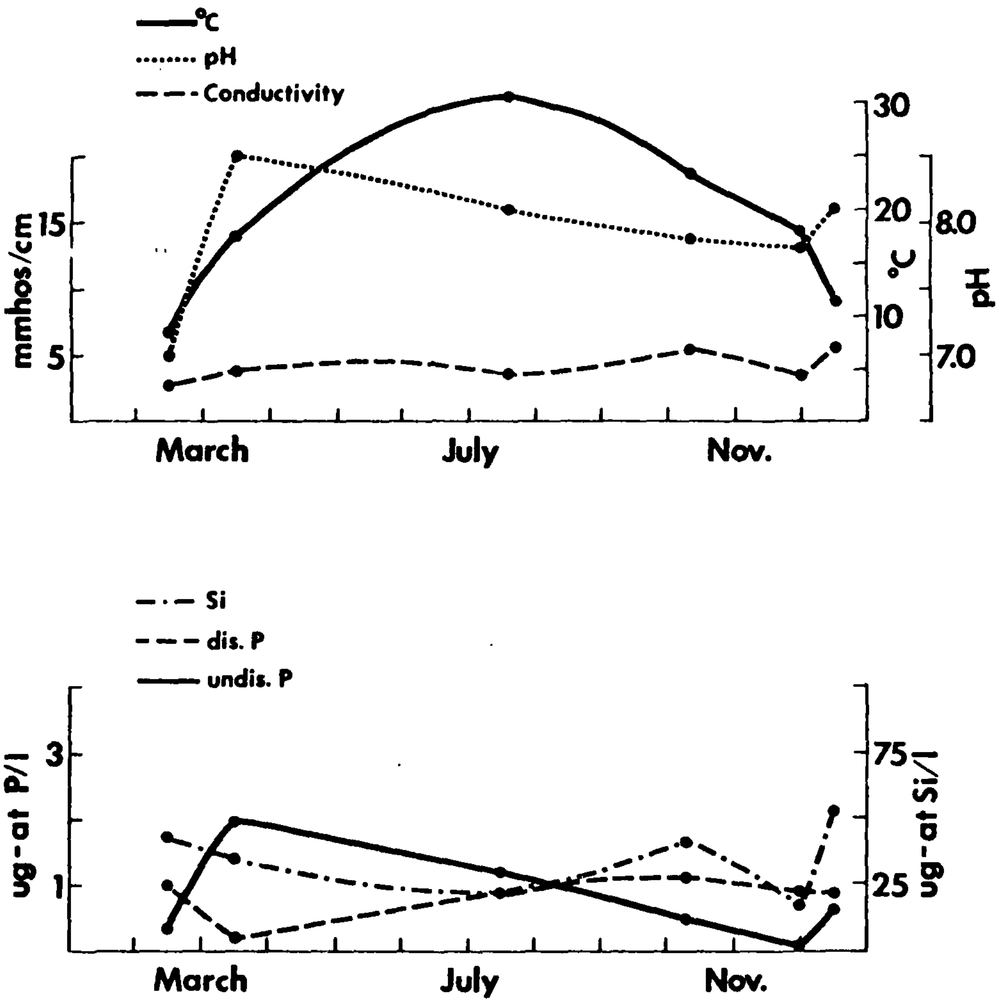


Figure 6. Depth and time averaged chemical data (Table A2) for shallow waters (0-3.5 m) at Survey Station 5 in Lake Pontchartrain, LA during 1978.

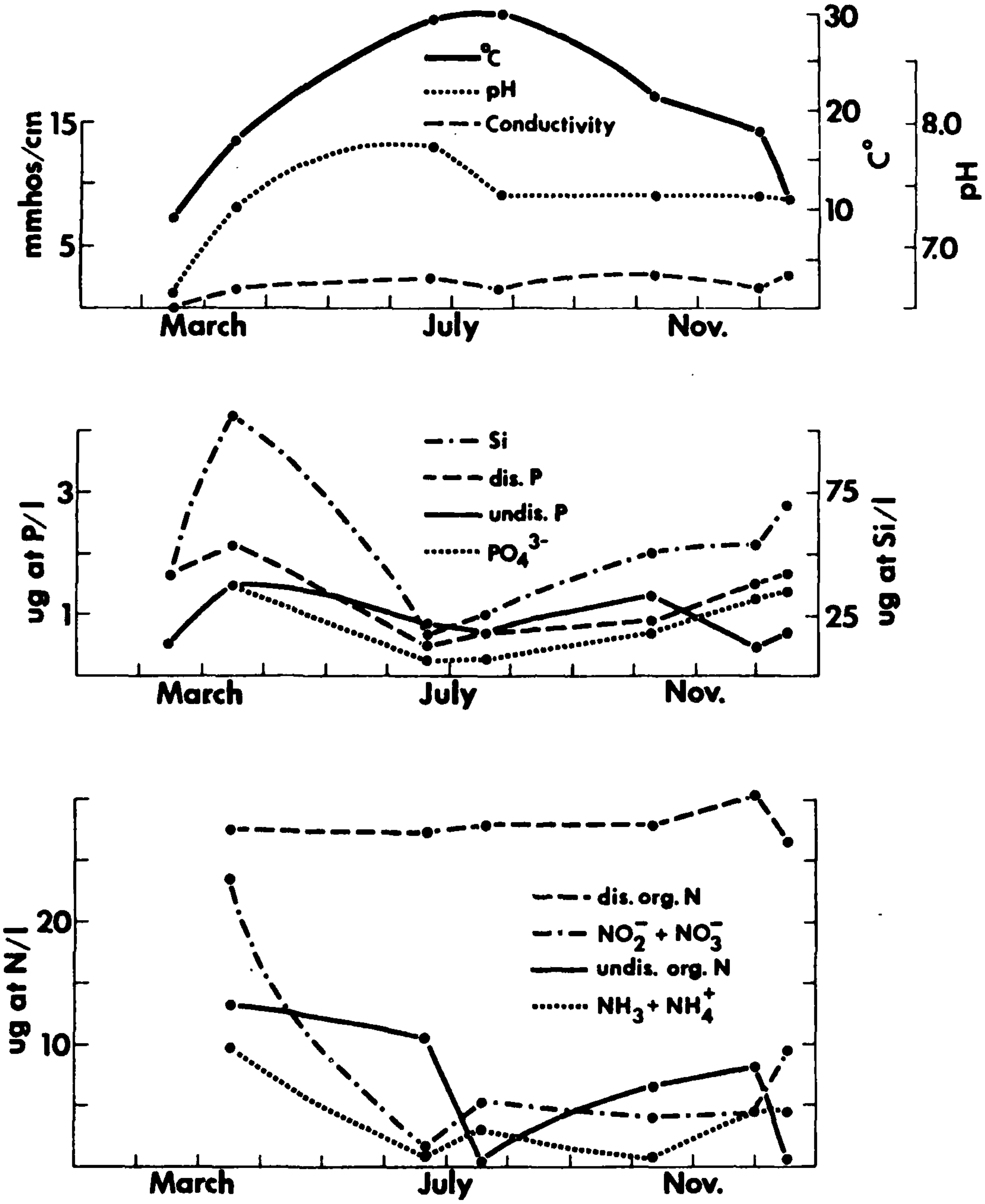


Figure 7. Depth and time averaged chemical data (Table A2) for shallow waters (0-2.5 m) at Master Station 1 in Lake Pontchartrain, LA during 1978.

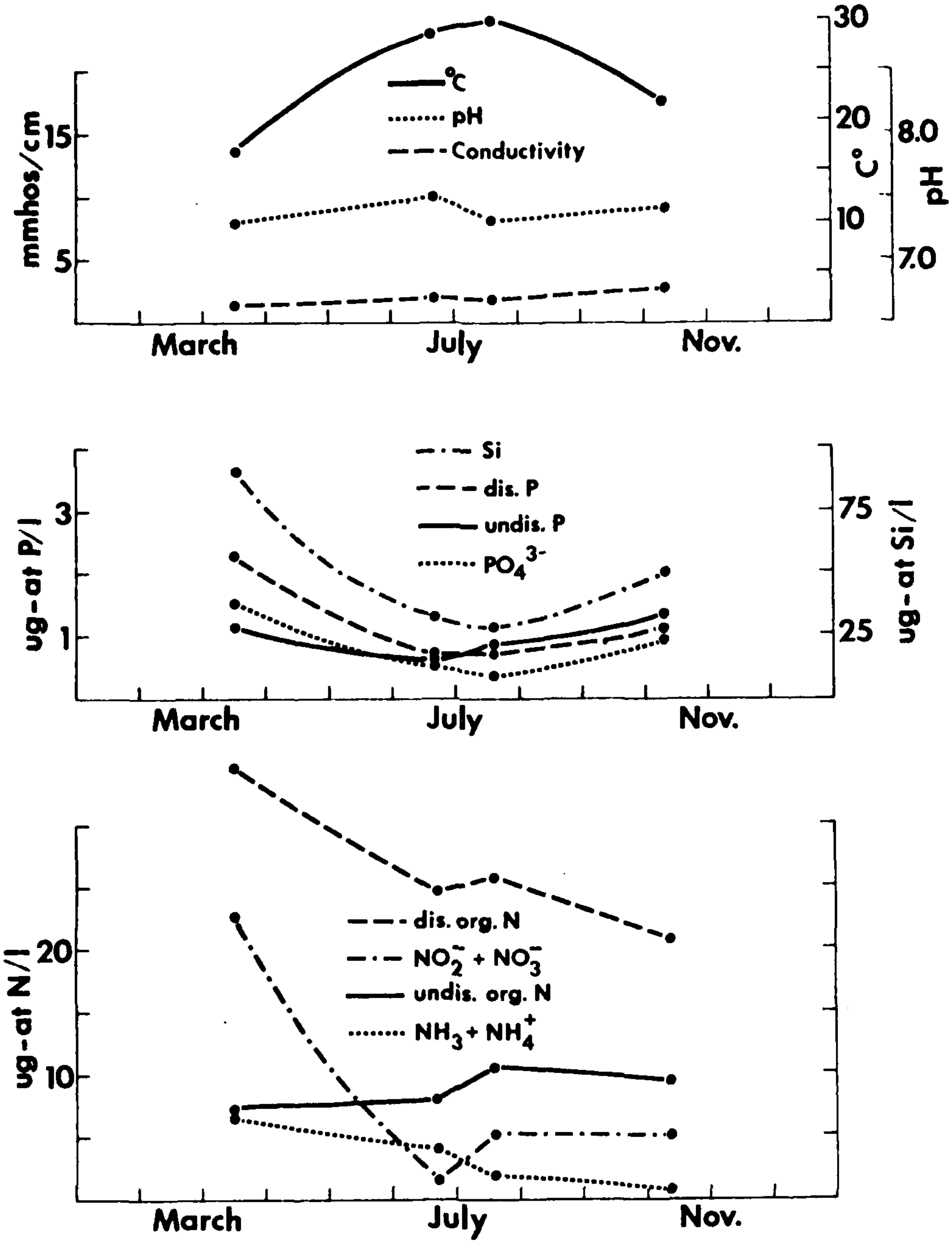


Figure 8. Time averaged chemical data (Table A2) for waters of 5 meter depth at Master Station 1 in Lake Pontchartrain, LA, during 1978.

Carbon concentrations (mg-at C l^{-1}) in the northwest quarter of the lake had the following ranges (Table A2): inorganic C, 0.19-0.77; dissolved organic C, 0.44-1.87; and undissolved organic C, 0.00-1.26. Complete seasonal carbon data in this area are only available from Master Station 1 and for the inorganic fraction, from Survey Station 3. Averaged inorganic carbon data (Table A2) for these stations are plotted versus time of year on Figure 9. Figures 10 and 11 contain similar plots for dissolved organic C and undissolved organic C, respectively.

Minimum values occurred in the summer for all carbon fractions. In addition, undissolved organic C concentrations stayed low in the fall and early winter. Maximum values occurred in the spring for both dissolved and undissolved C fractions.

II. Southwest Lake Pontchartrain

Survey Stations 4, 6, and 7 are located within the southwest quarter of the lake (Fig. 1). Nutrient input occurs from waste waters fed into the lake through canals in Jefferson Parish and from fresh waters flowing into the lake from Bayous Trepagnier and LaBranche and Walker Canal in St. Charles Parish. The proximity of this area to the saline water influx through the Inner Harbor Navigation Canal (IHNC) probably results in a higher salinity compared to the northwest quarter of Lake Pontchartrain.

Complete seasonal chemical data in the southwest quarter of the lake are available only for dissolved P, undissolved P, and Si at Survey Station 7. These data (Table A2) are plotted versus time of year on Figure 12. Concentrations (μg-at element l^{-1}) of P and Si in this area of the lake had the following ranges (Table A2): dissolved P, 0.41-6.55;

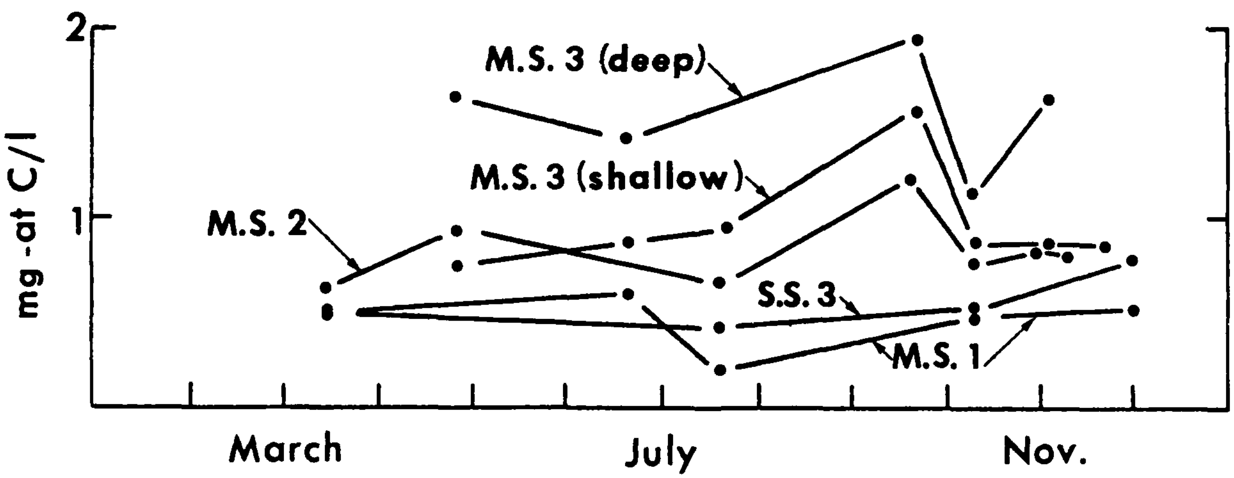


Figure 9. Depth and time averaged inorganic carbon data (Table A2) for shallow waters at Survey Station 3 (0-3.0 m), Master Station 1 (0-2.5 m), Master Station 2 (0-3.5 m), and Master Station 3 (0-3.5 m), and deeper waters (8-10 m) at Master Station 3 in Lake Pontchartrain, LA, 1978.

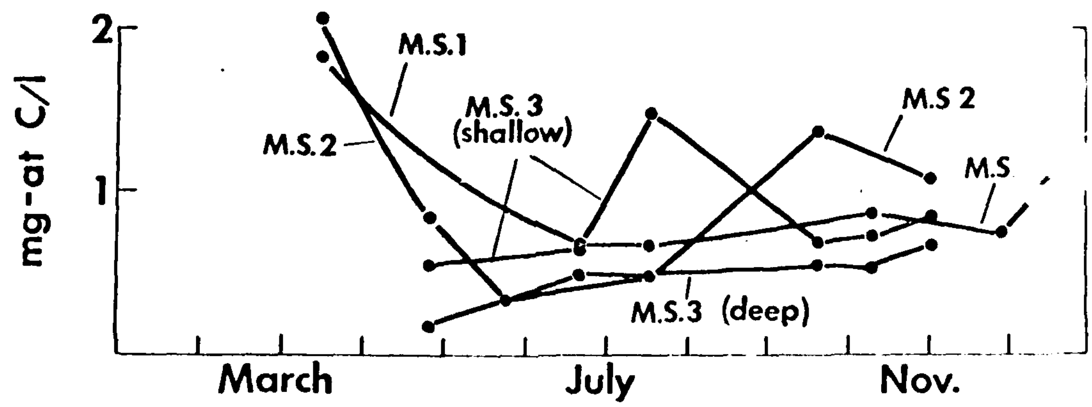


Figure 10. Depth and time averaged dissolved organic carbon data (Table A2) for shallow waters at Master Station 1 (0-2.5 m), Master Station 2 (0-3.5 m), Master Station 3 (0-3.5 m), and deeper waters at Master Station 3 (8-10 m) in Lake Pontchartrain, LA in 1978-1979.

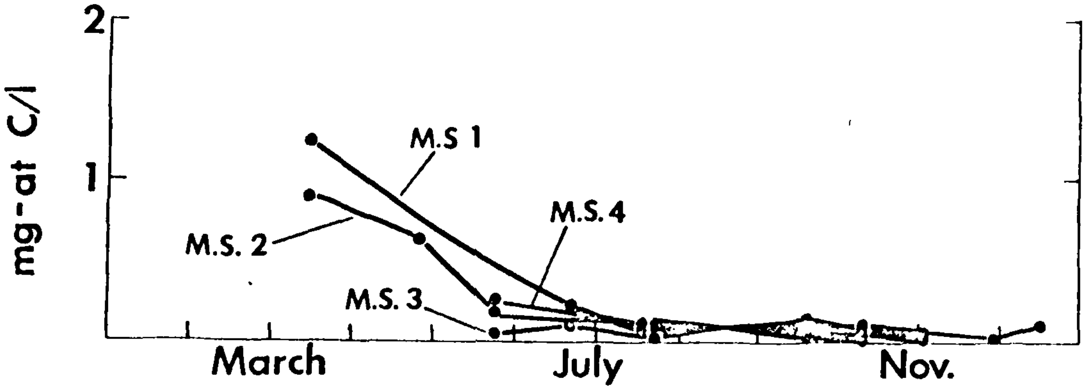


Figure 11. Depth and time averaged undissolved organic carbon data (Table A2) for shallow waters at Master Station 1 (0-2.5 m), Master Station 2 (0-?.5 m), Master Station 3 (0-3.5 m), and Master Station 4 (0-3 m) in Lake Pontchartrain, LA.

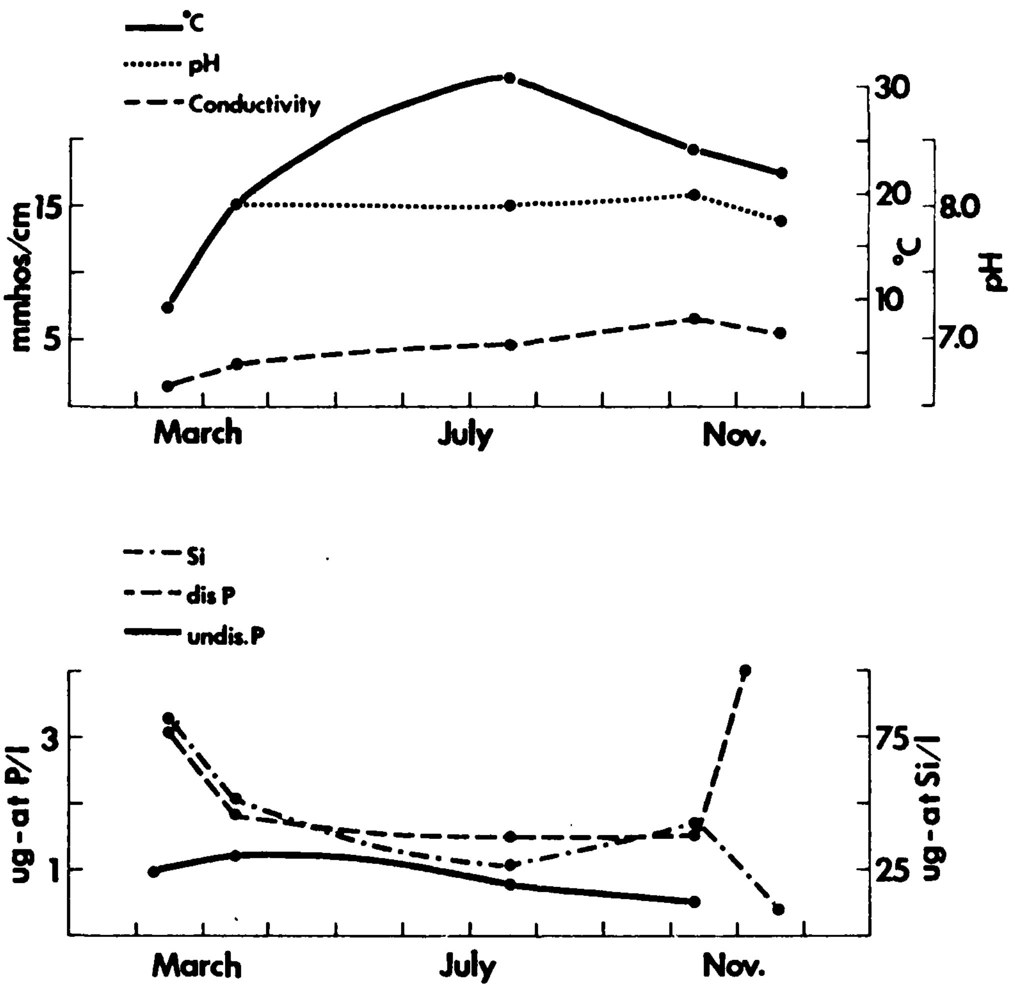


Figure 12. Depth and time averaged chemical data (Table A2) for shallow waters (0-2.5 m) at Survey Station 7 in Lake Pontchartrain, LA during 1978.

undissolved P, 0.36-3.60; and Si, 8-83. Data for other nutrient and carbon fractions are too incomplete to define their ranges.

Minimum values for dissolved P occurred in the summer, and maximum values occurred in the spring and winter. Silicate showed minimum concentrations in the summer and early winter and a maximum value in the spring. The dissolved P values in the southwest quarter were generally higher than in the northwest quarter.

III. Central Lake Pontchartrain

Master Station 2 is located near the center of Lake Pontchartrain (Fig. 1). Nutrient concentrations at this station should reflect all the nutrient inputs into Lake Pontchartrain: from fresh waters flowing into the lake at the north, northwest, and southwest shores; from waste water input along the southern shore; and from the influx of saline waters along the southeast and east shores. Averaged concentrations (Table A2) for the different nutrient fractions are plotted versus time of year on Figure 13 and 14 and for carbon fractions, on Figures 9-11.

Concentrations (μg-at element l^{-1}) of nutrients and (mg-at C l^{-1}) of carbon fractions in Central Lake Pontchartrain had the following ranges (Table A2): dissolved P, 0.38-1.65; undissolved P, 0.06-4.58; PO_4^{3-}, 0.03-1.00; Si, 12-112; $NH_3 + NH_4^+$, 0.0-21.1; $NO_2^- + NO_3^-$, 0.0-9.9; dissolved organic N, 10.4-30.6; undissolved organic N, 2.0-25.4; inorganic C, 0.55-1.22; dissolved organic C, 0.43-2.03; and undissolved organic C, 0.00-1.35.

The inorganic nutrients (Si, $NH_3 + NH_4^+$, $NO_2^- + NO_3^-$, and PO_4^{3-}) and dissolved P generally showed minimum concentrations during the summer and maximum values in the spring. Concentrations of the inorganic N

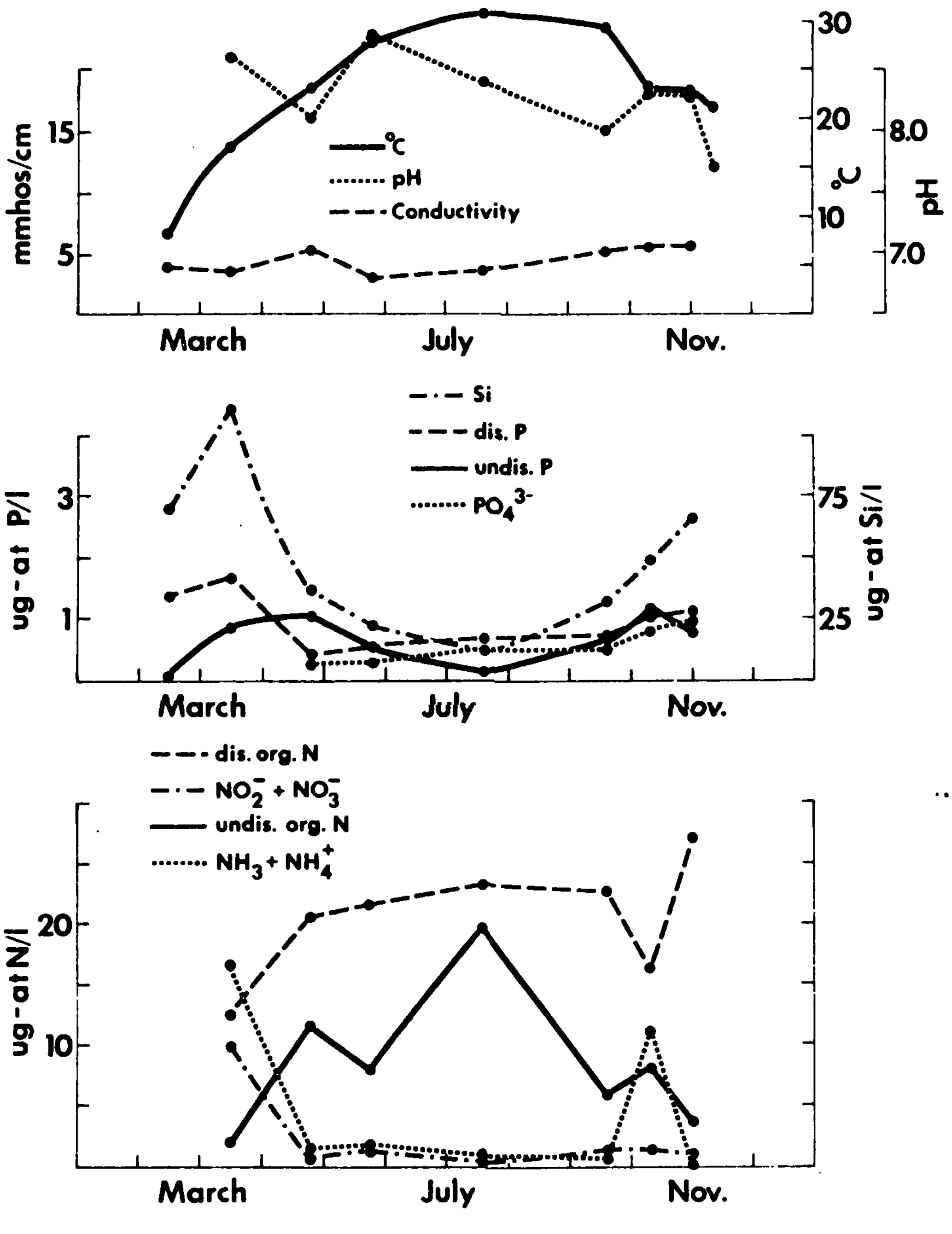


Figure 13. Depth and time averaged chemical data (Table A2) for shallow waters (0-3.5 m) at Master Station 2 in Lake Pontchartrain, LA during 1978.

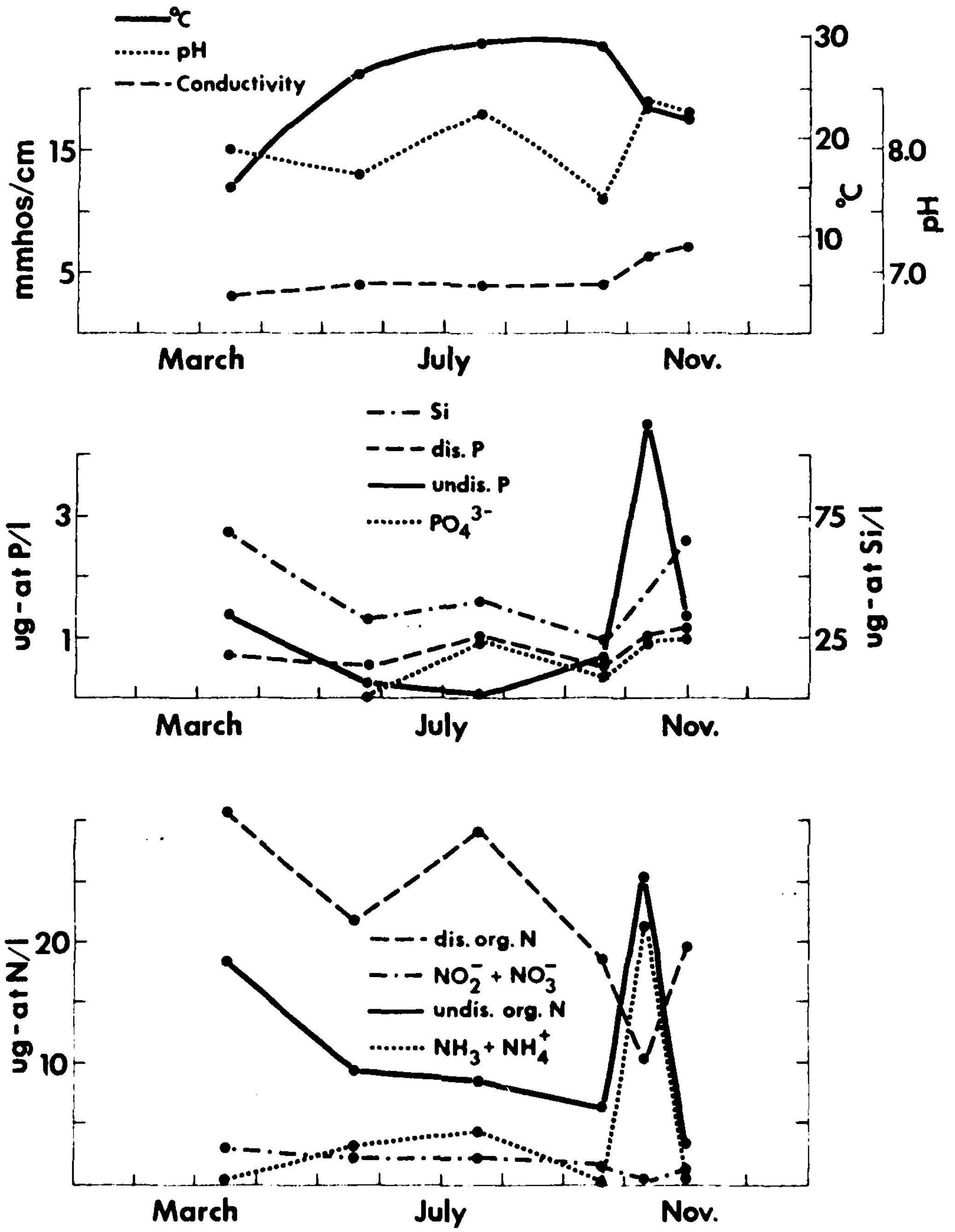


Figure 14. Time averaged chemical data (Table A2) for waters of 4 meter depth at Master Station 2 in Lake Pontchartrain, LA during 1978.

fractions remained low throughout the summer and fall except for a rapid increase and decrease in $NH_3 + NH_4^+$ during the fall. Inorganic C fluctuated seasonally; dissolved organic C had maximum concentrations in the spring and fall and a minimum value during the summer. Undissolved organic C values decreased from a spring maximum and stayed low during the summer and fall.

IV. East Lake Pontchartrain

Survey Stations 8 through 14 and Master Stations 3 and 4 are located within the eastern third of Lake Pontchartrain (Fig. 1). Nutrient and carbon chemistries should reflect waste water input from the New Orleans area; the influx of saline water through The Rigolets, Chef Menteur Pass, and the IHNC; and fresh waters from the Pearl River and Bayous Lacombe, Liberty, and Bonfouca (Fig. 1). Unfortunatley, only scattered data are available from the survey stations; however, summer and fall seasonal data exist for Master Stations 3 and 4. These data are shown on Figures 9-11 and 15-18 in which the averaged nutrient and carbon concentrations (Table A2) are plotted versus time of year.

The data shown for Master Stations 3 and 4 are not necessarily typical of data from the rest of the eastern third of Lake Pontchartrain. Data from these two stations are influenced by their locations near the tidal passes. Master Station 3 is located at the lake outlet of the IHNC. Waters flowing out of this canal are a mixture of saline waters from the IHNC, Mississippi River water, and probably waste waters from the New Orleans area. Master Station 4 is located at the mouth of The Rigolets. Feeding through The Rigolets are a mixture of saline waters from Lake Borgne and fresh waters from the Pearl River. The total

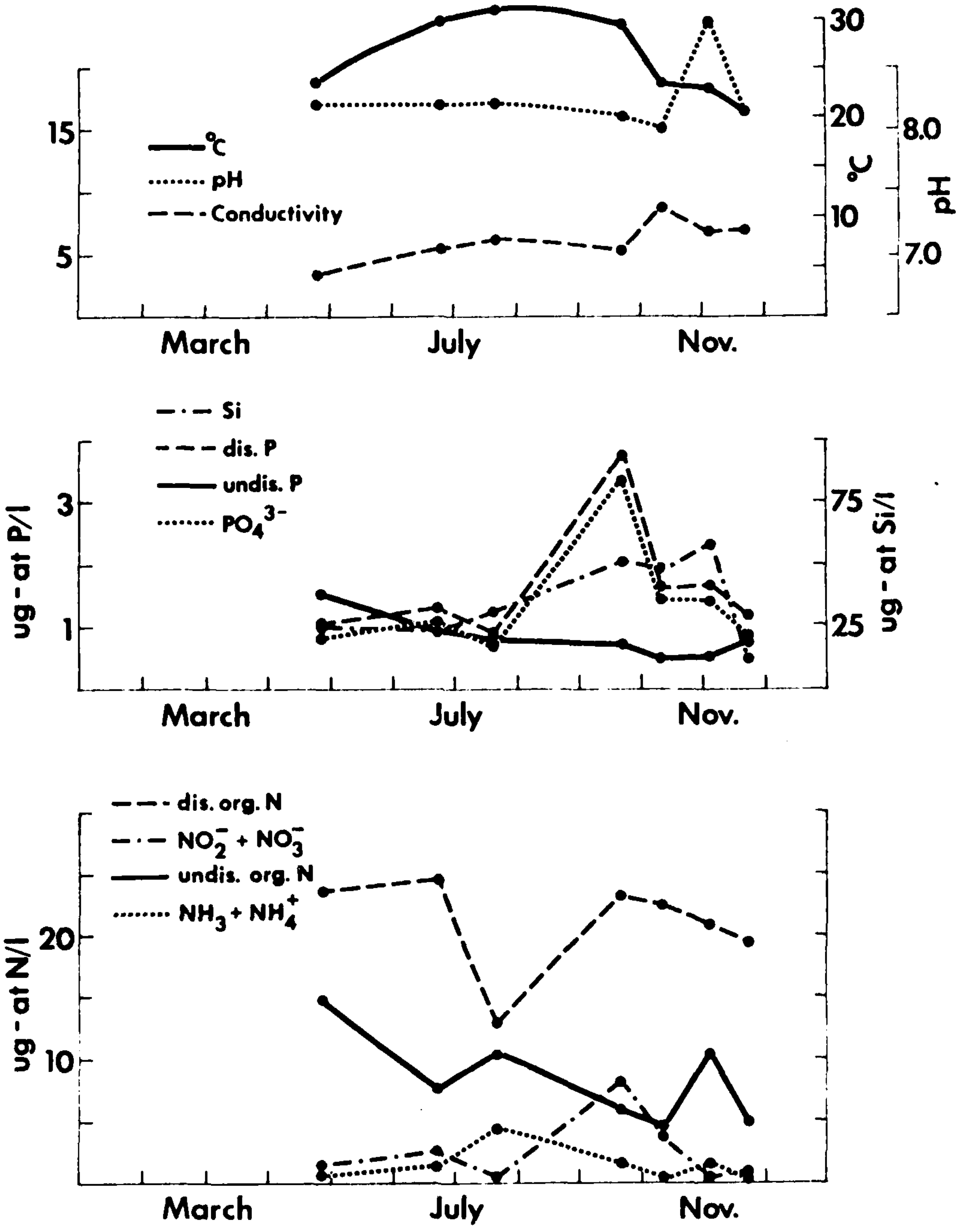


Figure 15. Depth and time averaged chemical data (Table A2) for shallow waters (0-3.5 m) at Master Station 3 in Lake Pontchartrain, LA during 1978.

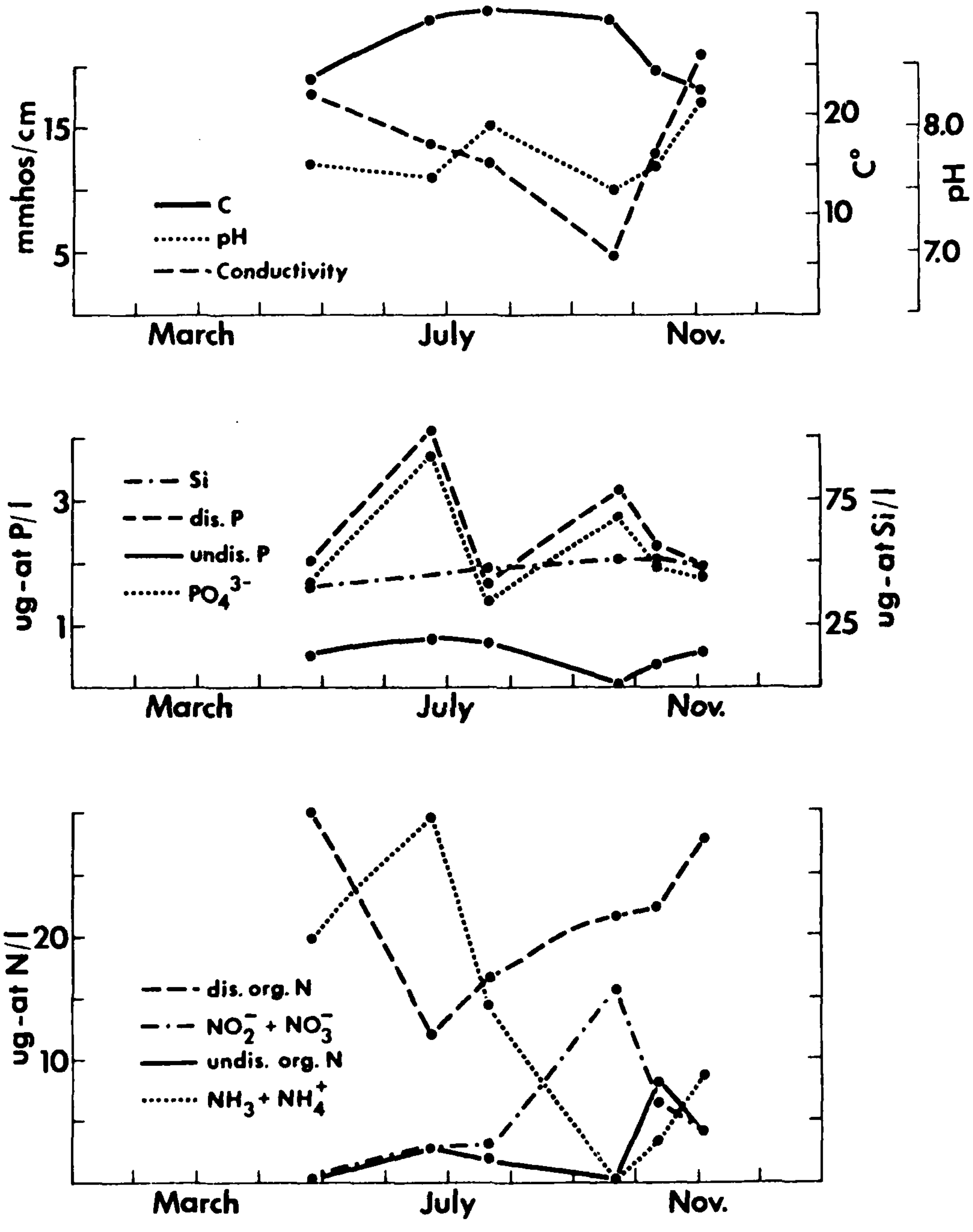


Figure 16. Time averaged chemical data (Table A2) for waters of 8 to 10 meter depth at Master Station 3 in Lake Pontchartrain, LA during 1978.

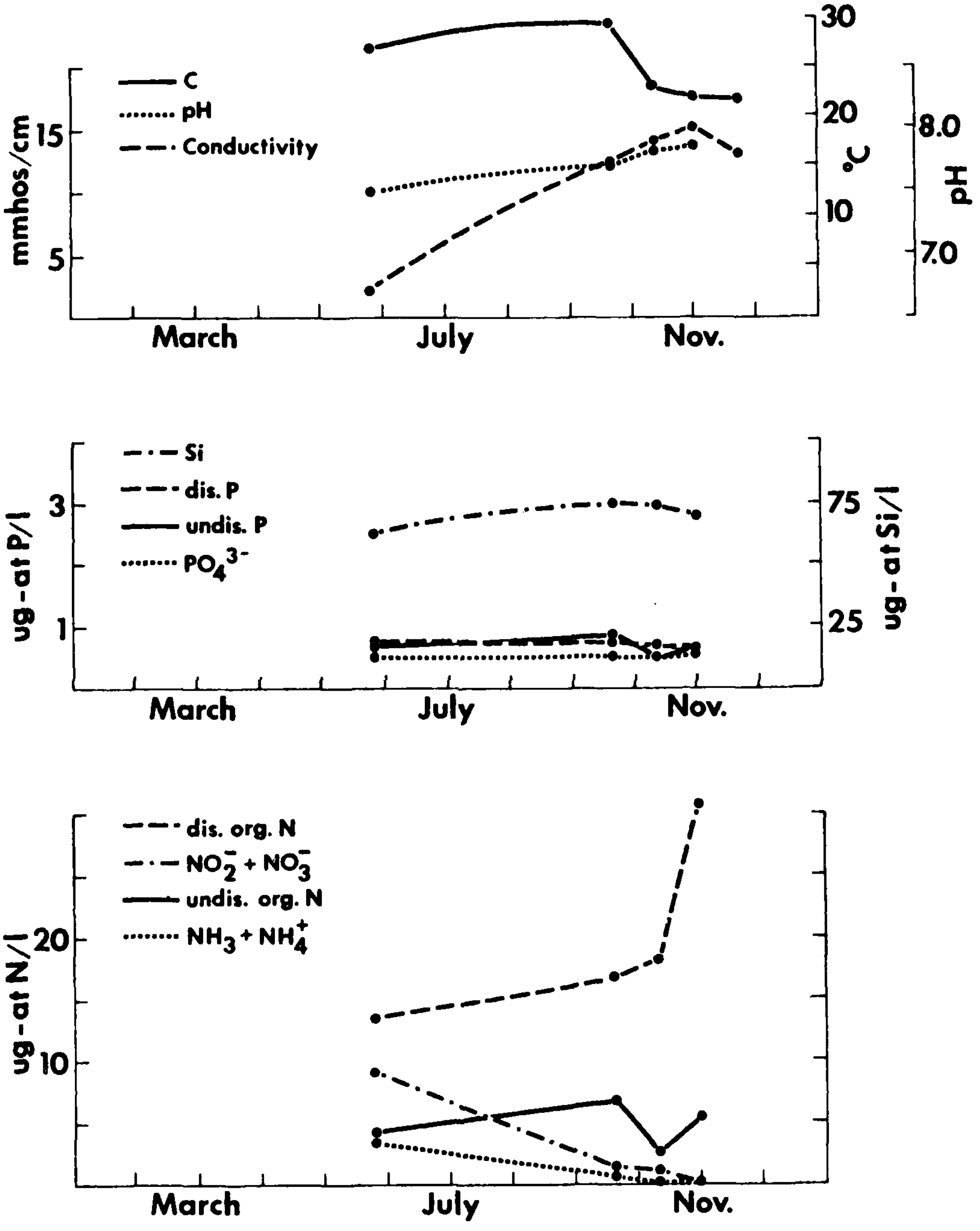


Figure 17. Depth and time averaged chemical data (Table A2) for shallow waters (0-3 m) at Master Station 4 in Lake Pontchartrain, LA during 1978.

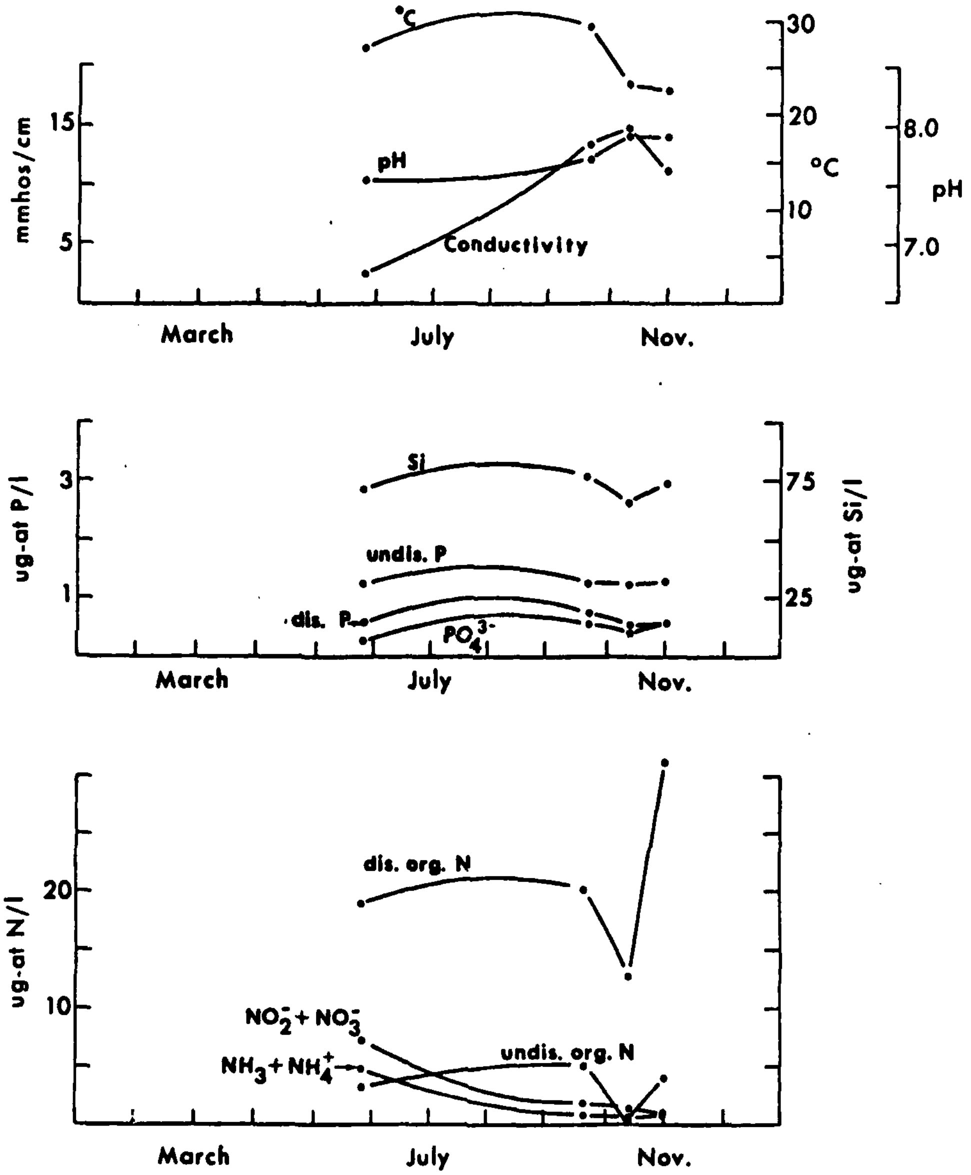


Figure 18. Time averaged chemical data (Table A2) for waters of 8 to 10 meter depth at Master Station 4 in Lake Pontchartrain, LA during 1978.

depths at these two stations are generally at least twice as great as depths at the other stations, and a salt wedge generally exists at Master Station 3 as shown in the data in Tables A1 and A2.

Concentrations (μg-at element l^{-1}) of nutrients and (mg-at C l^{-1}) of carbon fractions in the eastern third of Lake Pontchartrain, excluding the deep 8-10 meter waters at Master Stations 3 and 4, had the following ranges (Table A2): dissolved P, 0.10-3.79; undissolved P, 0.10-1.54; PO_4^{3-}, 0.43-3.65; Si, 12-88; NH_3 + NH_4^+, 0.0-14.4; NO_2^- + NO_3^-, 0.0-16.3; dissolved organic N, 13.0-31.3; undissolved organic N, 1.9-14.9; inorganic C, 0.57-1.94; dissolved organic C, 0.52-6.24; and undissolved organic C, 0.00-0.62. The deep (8-10 meter) waters at Master Stations 3 and 4 had the following concentration ranges (Table A2): dissolved P, 0.45-4.08; undissolved P, 0.00-1.25; PO_4^{3-}, 0.26-3.67; Si, 42-77; NH_3 + NH_4^+, 0.0-29.6; NO_2^- + NO_3^-, 0.0-15.9; dissolved organic N, 12.0-28.6; undissolved organic N, 0.0-8.0; inorganic C, 0.94-1.96; dissolved organic C, 0.19-0.64; and undissolved organic C, 0.01-0.67.

Trends in nutrient concentrations at Master Station 3 showed rapid increases and decreases with time that were poorly correlated between shallow and deep waters. Dissolved P and PO_4^{3-} were generally higher at Master Station 3 than elsewhere in the lake, with the exception of the southwest quarter. Trends at Master Station 4 correlated well between the shallow and deep waters and with the other areas of the lake. At Master Station 4, low concentrations occurred in the summer and fall for dissolved P, PO_4^{3-}, NH_3 + NH_4^+, NO_2^- + NO_3^-, and undissolved organic C. Concentrations of inorganic C were highest in the eastern half of the lake.

DISCUSSION

I. Nutrients

Lake Pontchartrain is a shallow, brackish lake with a salinity gradient between freshwater Lake Maurepas at its western end and brackish Lake Borgne at its eastern end (conductivity data, Tables A1 and A2, also Swenson, Chapter 4). River input is concentrated along the shores of the western half of the lake and is at a maximum during late winter and spring (Saucier 1963), which was the period of lowest salinities in the lake. Nutrient concentrations in Tables A1 and A2 spanned the same range as concentrations in the vicinity of nearby Lake Borgne (Barrett et al. 1971), falling between those in the nutrient-rich Barataria Bay estuary (Seaton 1979) and average nutrient-depleted sea water (Spencer 1975). Nutrient concentrations in the nearshore area of Barataria Bay are strongly influenced by proximity to the discharge of the Mississippi River and its high and low stages (Ho and Barrett 1975). Accordingly, a correlation between river input into Lake Pontchartrain and seasonal nutrient levels in the lake would not be unexpected.

By analogy with Mississippi River water and the Barataria Bay estuary, river input into Lake Pontchartrain should raise concentrations of $NO_2^- + NO_3^-$, PO_4^{3-}, Si, and organic N in the lake (Ho and Barrett 1975). Swamps and marshes dominate the western and eastern shorelines, respectively, and water input from these sources should increase lake concentrations of $NH_3 + NH_4^+$, organic N, and total phosphorus (analogy with Barataria Basin, Seaton 1979). River input is concentrated during the yearly flood stage; however, water input from swamps and marshes depends also on the preciptation, which averages 150-163 cm annually in the vicinity of the lake (Saucier 1963).

Industrial and domestic wastes enter the lake from the New Orleans area along the southern shore. Nutrient contents of these waste waters should be high in organic N and P, NH_3 + NH_4^+, and PO_4^{3-}. Saline waters enter through the three tidal passes on the eastern and southeastern shores. These passes also serve as the major outlets of the lake. Saline waters from the Gulf of Mexico were originally nutrient poor but have been diluted by fresh waters prior to entering the lake. Their nutrient content will be controlled by that dilution.

Within the lake, the bottom sediments are both a source and sink for nutrients in the water column. Stirring up the sediments through water turbulence or dredging probably acts to release nutrients trapped in the sediments, e.g., NH_3 and NH_4^+ formed under anoxic conditions in the lake bottom. Nutrient scavenging by sediment particles falling through the water column will act as a sink.

The effect of the inputs and sinks for nutrients will be modified by the ecological community within the lake. Phytoplankton assimilate inorganic nutrients. Excretion and the death of lake organisms caused by changes in salinity, temperature, etc., will release organic nutrient fractions and Si. Subsequent biogenic oxidation of the organic nutrients will regenerate the inorganic fractions. The importance of inorganic assimilation by organisms indicates that the absence of one or more of these fractions may limit growth. In such a case, the concentrations of phytoplankton would show a significant decrease lakewide. For a detailed study of the interactions between the plankton community and nutrients in Lake Pontchartrain, the reader is referred to Chapters 7 and 8.

Nutrient trends given in the "Results" section are summarized below.

1) PO_4^{3-}, dissolved P, and Si concentrations were usually high in spring, low in summer, and increased in the fall.

2) $NH_3 + NH_4^+$ and $NO_2^- + NO_3^-$ levels were usually high in spring, low in summer, and remained low in the fall.

3) Organic N fractions and undissolved P content did not show consistent lake-wide trends.

4) The highest values of PO_4^{3-} and dissolved P usually occurred along the south side of the lake. Nutrient trends at Master Station 3 were inconsistent with the rest of the lake.

The springtime highs for the inorganic nutrients and dissolved P are apparently related to maximum river input and possibly to stream flooding through swamps and marshes into the lake. Summer depletions of these nutrient fractions could be explained through assimilation by organisms such as phytoplankton. The low values in the fall for $NH_3 + NH_4^+$ and $NO_2^- + NO_3^-$ may imply inorganic N is growth limiting for lake organisms (a conclusion also reached by Dow and Turner, Chapter 7). Increases in PO_4^{3-} and dissolved P concentrations in the fall could be related to nutrient release from bottom sediments suspended by increased water turbulence. This suspension does not necessarily show up as increased turbidity because increased salinity tends to flocculate the sediment. Increases in Si levels in the fall could result from dissolution of diatoms killed by increasing salinities and/or decreasing temperatures. Higher than normal values for PO_4^{3-} and dissolved P along the south side of the lake are presumably caused by pollution from New Orleans. Similarly, inconsistent trends at Master Station 3 probably reflect input of industrial and domestic wastes into the IHNC.

II. Carbon

Carbon fractions in Lake Pontchartrain include inorganic C (CO_2, H_2CO_3, HCO_3^-, and CO_3^{2-}) and dissolved and undissolved organic C. Inorganic C is produced by respiration in animal organisms, by oxidation of organic C by bacteria, and by dissolution of carbonate minerals. External sources include inputs of saline water and fresh water and direct exchange with the atmosphere. Concentrations of inorganic C in average sea water and river water are 2.59 and 0.96 mg-at C l^{-1}, respectively (Garrels and Mackenzie 1971). Saline water input should increase concentrations in the lake; river input should decrease them. Waters input from adjacent fresh water marshes and swamps should have low inorganic C concentrations, as implied by their neutral to acidic pH values. However, waters input from saline marshes could have high inorganic C concentrations due to aqueous CO_2 production from SO_4^{2-} reduction. Inorganic C is used up: in the conversion to organic C during photosynthesis of plant organisms; by organic precipitation of calcite, aragonite, and apatite to form shells, plant walls, and the teeth and bones of aquatic animals; and by the inorganic precipitation of carbonate minerals.

Undissolved organic C can be organic detritus, living plant animal organisms derived from the aquatic food chain, or formed in situ from dissolved organic C. River input and water input from adjacent swamps and marshes should increase lake concentrations above the low values associated with sea water, e.g., 0.007 to 0.011 mg-at C l^{-1} for the North Atlantic ocean (Parsons 1975).

Dissolved organic C is produced by the excretion of animal organisms, the release of photosynthesis products by algae, and the

autolytic and decay processes following the death of organisms. Dissolved organic C concentrations in average river water (Garrels and Mackenzie 1971) and in sea water in the Gulf of Mexico (Williams 1975) are 0.80 and 0.07 mg-at C l^{-1}, respectively. Dissolved organic C concentrations in Tables A1 and A2 are sometimes higher than those in average river water. Values as high as 50 mg-at C l^{-1} of organic C are found in swamps and bogs (Stumm and Morgan 1970). Accordingly, dissolved organic C concentrations in the lake should be increased by water flow from the adjacent swamps and marshes and decreased by saline water input. Dissolved organic C is used up by oxidation to inorganic C and also by conversion to undissolved organic C.

Carbon trends in the "Results" section are summarized below.

1) Inorganic C concentrations increased spatially from west to east and southeast across Lake Pontchartrain.

2) Dissolved organic C levels were high in spring, low in the summer, and increased in the fall.

3) Undissolved organic C levels were high in spring and nearly nondectable in the summer and fall.

The spatial trend in inorganic C concentrations could be related to the higher inorganic C content of saline water input along the eastern and southeastern shores relative to the lower inorganic C content of fresh water input along the western shore of the lake. The spatial trend can be explained by simple mixing of these waters. Lower than average river water concentrations occur in the western half of the lake and point to the significance of the low inorganic C levels in fresh waters draining the swamps along the western shore.

Spring highs in both dissolved and undissolved organic C are apparently related to maximum river input and stream flooding through swamps and marshes into the lake. Decreases in summer and fall could be due to biogenic oxidation and the absence of significant inputs.

CONCLUSIONS AND SUMMARY

Water samples for nutrient and carbon analyses were collected in Lake Pontchartrain at 14 survey stations and 4 master stations. Samples were taken as a function of depth on a monthly to quarterly and sometimes semiannual basis in 1978.

The observed seasonal trends and spatial variations are listed below.

1) PO_4^{3-}, dissolved P, and Si concentrations generally were high in spring, were low in summer, and increased in the fall.

2) $NH_3 + NH_4^+$ and $NO_2^- + NO_3^-$ levels usually were high in spring, were low in summer, and remained low in the fall.

3) The south side of the lake was characterized by high PO_4^{3-} and dissolved P contents.

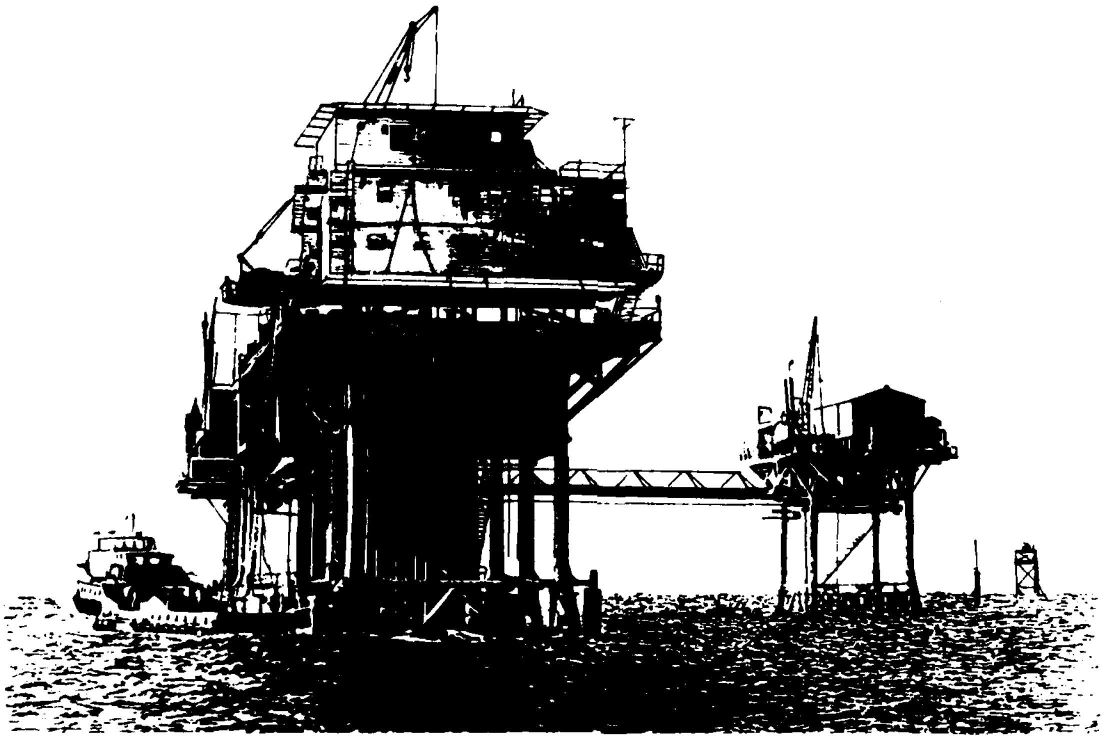
4) Inorganic C concentrations increased spatially from west to east and southeast across Lake Pontchartrain.

5) Dissolved organic C levels were high in spring, were low in the summer, and increased in the fall. Undissolved organic C levels were also high in spring and were undetectable in the summer and fall.

High concentrations in the spring for inorganic nutrients, dissolved P, and the organic C fractions could be caused by maximum river input and by stream flooding through adjacent swamps and marshes into the lake. Assimilation of inorganic nutrients by organisms could explain their low

concentrations in the summer. Increased levels of Si in the fall may result from the death and dissolution of diatoms. Higher PO_4^{3-} and dissolved P contents in the fall could be due to nutrient release from suspended sediments. Continued low values of inorganic N fractions in the fall imply N is growth limiting for some lake organisms.

High levels of PO_4^{3-} and dissolved P along the south shore may be due to pollution from the New Orleans area. Spatial gradation of inorganic C levels across the lake can be explained by mixing fresh waters with saline waters.



Petroleum platform complex

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APPENDIX 1

CHEMICAL DATA

Chemical data from the survey and master stations in Lake Pontchartrain are listed in Table A1. For additional chemical data from Lake Pontchartrain and adjacent marsh areas, see Chapter 7 by Dow and Turner, Chapter 9 by Cramer and Day, and Miller (1980). Nutrient and carbon fractions listed in Table A1 that were computed by the addition and subtraction of analyzed fractions are as follows: $NO_2^- + NO_3^-$ = TIN - $(NH_3 + NH_4^+)$; dissolved organic N = dissolved Kjeldahl N - $(NH_3 + NH_4^+)$; undissolved organic N = total Kjeldahl N - dissolved Kjeldahl N; undissolved P = total P - dissolved P; and undissolved organic C = total organic C - dissolved organic C. In a few cases, the resulting computed values were negative, and these were set to zero. The ± precision estimates refer to the average standard deviations listed in Table 1 computed from the sets of triplicate field replicates. Twice the average standard deviation obtained from the sets of laboratory replicates (Table 1) was used to estimate precision for chlorosity because data were not available for the sets of triplicate field replicates. In the case of a nutrient or carbon fraction computed by the addition and subtraction of analyzed fractions, the largest average standard deviation was used as a precision estimate. A better and lower estimate would have been a weighted average of the average standard deviations of the analyzed fractions; however, the above procedure is adequate for this study.

Depth and time averaged chemical data for the survey and master stations are reported in Table A2. These data were computed from those listed in Table A1. For each reported average value, the ± value refers

to a 95% confidence interval equal to 1.96 times the standard error of the mean. The absence of a ± value means the reported value was not an average, i.e., only one analysis was available.

Table [illegible]. Chemical Data from Lake Pontchartrain, LA During 1978*

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. $\frac{\text{mmhos}}{\text{cm}}$	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							ug-at/l								mg-at/l		
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.60
Survey Station 1																	
2/14-8	1	0.0	7.8	7.2	2.4	0.79						0.97	0.97	22			
2/14-8	2	1.5			2.4	0.82						0.77	0.90	38			
3/15-9	33	0.0	18.3	7.2	4.1							1.42	1.55	45			
3/15-9	34	1.5	15.5	7.4	2.4							0.52	1.29	40			
7/18-8	295	2.5	30.0	7.4	2.0		3.0	1.4				0.42	1.29			0.44	0.30
10/10-8	404	0.0	21.0	7.3	1.9		0.2	1.7				0.94	1.48	56	0.47		
10/10-8	405	1.5	21.0	7.3	2.2		4.4	3.0				1.81	0.00	59			
Survey Station 2																	
2/14-10	3	0.0	7.6	6.7	2.7	0.84						0.97	1.32	47			
2/14-10	4	1.5			2.7	0.87						0.45	1.03	18			
3/15-10	35	0.0	18.5	8.4	4.2							0.97	1.03	48			
3/15-10	36	2.0	16.6	8.3	1.4							1.55	0.00	43			
7/16-9	296	0.0	30.0	7.6	2.5		0.0	1.6				0.52	1.26	5	0.62	0.62	0.16
7/15-9	297	2.5	30.0	7.9	2.5		7.1	0.0				1.81	0.00	62	0.53	0.51	0.23

*± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	$NH_3 + NH_4^+$	$NO_2^- + NO_3^-$	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - - - - - - - - - - -	- - - -	µg-at/l	- - - -	- - - -	- - - -	- - - -	- - - -	- - -	mg-at/l	- - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Survey Station 2 (Continued)																	
9/21-10	382	0.0	29.0	7.7	2.6		0.3	0.6				0.26	0.81	33	1.01		
9/21-10	383	1.0	29.0	7.7	2.5		0.6	1.4				0.58	1.32	43	0.94		
10/10-9	406	0.0	21.3	7.5	3.6		0.9	4.0				0.39	0.94	32	0.56		
10/10-9	407	3.0	21.4	7.6	2.2		0.0	0.4				0.61	0.39	43	0.58		
Survey Station 3																	
2/14-10	5	0.0	8.2	6.8	1.3	0.49						1.13	1.19	48			
2/14-10	6	1.0	8.1	6.3	1.3	0.50						1.74	0.65	72			
2/14-10	7	3.0	8.1	6.4	1.5	0.46						1.33	1.10	40			
3/15-12	37	0.0	19.2	7.4	3.2							2.14	1.42	57			
3/15-12	38	1.5	16.5	7.4	4.2							0.62	8.46	40	0.56		
3/15-12	39	3.0	15.9	7.4	3.6							0.03	1.65	28	0.68		
7/18-11	301	0.0	30.0	8.2	2.7		2.7	0.6				0.16	1.07		0.45	0.45	0.37
7/18-11	302	3.0	30.0	7.9	2.7		1.6	0.5				0.16	1.32	7	0.41	0.46	0.42

[*] ± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. $\frac{mmhos}{cm}$	Cl^- g/1	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - - -	- - - -	- - - -	- - ug-at/1 - -	- - - -	- - - -	- - - -	- - - -	- - - -	mg-at/1	- - - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
								Survey Station 3 (Continued)									
10/10-10	408	0.0	22.0	7.4	2.7		0.0	0.7				0.94	0.58	43	0.54		
10/10-10	409	2.0	22.0	7.5	2.8		1.7	2.1				0.71	0.87	35			
10/10-10	410	3.0	22.2	7.4	2.6		1.1	0.0				0.10	0.03	45	0.50		
12/01-11	556	0.5	17.8	7.7	5.5		1.4	1.6	24.7	8.1	0.55	0.71	0.55	49	0.77	0.52	0.00
12/14-8	619	0.0	12.0	7.5	3.8		0.0	2.9	28.8	6.4	0.36	0.58	1.00	11		2.38	0.10
12/14-8	620	2.0	12.0	7.4	5.0		1.0	4.4	26.2	8.6	0.81	1.03	0.87	16		1.35	0.12
								Survey Station 4									
2/14-12	11	0.0	8.4	7.0	1.4	0.49						1.58	0.55	78			
2/14-12	12	1.0	8.0	6.9	1.4	0.59						1.29	1.32	55			
3/15-14	43	0.0	19.8	8.8	5.2							0.58	1.71	12			
3/15-14	44	2.5	15.3	8.3	4.0							0.23	5.49	8			
10/10-12	414	0.0	22.5	7.7	3.9		0.4	2.6				0.61	0.58	32	0.60		
10/10-12	415	2.0	22.1	7.7	3.9		0.8	1.4				0.77	0.81	32	0.47		

*± values refer to overall prevision estimates as discussed in the test. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. $\frac{mmhos}{cm}$	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							µg-at/l								mg-at/l		
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
								Survey Station 5									
2/14-13	13	0.0	8.7	7.1	2.5	0.82						1.16	0.19	25			
2/14-13	14	1.0	8.6	7.0	2.5	0.80						1.23	0.10	87			
2/14-13	15	3.0	8.6	7.0	2.7	0.90						0.65	0.74	18			
3/14-11	24	0.0	19.5	8.5	3.9		4.1	0.2	28.2	1.1		0.13	1.65	42	0.62	1.79	0.69
3/14-11	25	0.5	17.5	8.6	3.9		5.6	0.9	26.1	5.1		0.23	3.00	35	0.61	1.36	0.54
3/14-11	26	1.5	17.0	8.3	4.0		5.9	0.7	25.8	6.3		0.19	2.10	37	0.68	2.12	0.85
3/14-15	27	0.0	18.0	8.8	3.8		1.3	2.0	29.3	7.5		0.19	3.42	35		2.91	1.55
3/14-15	28	0.5	16.9	8.8	3.8		1.6	1.7	38.6	0.0		0.23	2.13	38		3.93	1.29
3/14-15	29	1.5	14.6	8.4	4.0		3.5	2.0	26.0	3.4		0.13	2.36	37	0.63	2.77	1.32
3/14-17	30	0.0	19.0	8.9	3.8		1.7	2.9	44.7	0.0		0.16	1.78	35		1.89	0.22
3/14-17	31	0.5	17.9	8.9	3.8		2.6	4.0	29.6	2.0		0.26	1.61	37		1.16	1.25
3/15-15	45	0.0	20.4	8.9	4.3							0.00	1.03	13			
3/15-15	46	1.5	15.8	8.0	4.6							0.45	1.26	43	0.57		
3/15-15	47	2.5	14.8	7.8	2.5							0.00	1.42	33	0.69	0.22	0.03
7/18-17	310	0.0	30.5	8.5	3.5		4.3	0.0				0.36	1.03	10			
7/18-17	311	3.5	30.0	7.7	3.5		13.3	0.0				1.32	1.39	32			

* ± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. $\frac{\text{mmhos}}{\text{cm}}$	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - - - -	- - - - -	- - - - -	- - - µg-at/l	- - - - -	- - - - -	- - - - -	- - - - -	- - -	mg-at/l	- - - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Survey Station 5 (Continued)																	
10/10-13	416	0.0	24.0	7.9	5.5		0.4	0.5				1.07	0.58	40	0.69		
10/10-13	417	3.5	23.0	7.9	5.1		1.6	0.0				1.13	0.45	43	0.71		
12/01-10	555	0.5	17.7	7.8	3.4		2.1	1.4	27.2	0.0	0.61	0.90	0.00	17	0.67	0.62	0.00
12/15-8	651	0.0	11.2	8.1	5.5		0.0	2.2	23.5	6.4	0.58	0.84	0.65	52			
Survey Station 6																	
2/14-15	16	0.0	12.7	7.3	1.1	0.40						4.39	0.0	70			
2/14-15	17	1.0			1.1	0.46						4.55	0.65	70			
2/14-15	18	1.0	11.5		1.1	0.38						5.46	0.00	38			
2/15-17	48	0.0	19.3	7.9	2.8							1.19	2.68	72	0.62	0.18	0.10
2/15-17	49	1.0			2.9							1.65	2.13	75	0.64		
2/15-17	50	2.0	18.1	7.6	3.1							1.65	0.71	43	0.68		
7/18-15	308	0.0	31.0	7.8	5.2		7.7	0.0				2.42	1.29	25			
7/18-15	309	2.0	31.0	7.8	5.3		3.4	2.9				3.07	0.26	70			

*± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. $\frac{\mu mhos}{cm}$	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - - - - - - - - - -	- - - -	- - - - ug-at/l	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - mg-at/l	- - - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Survey Station 6 (Continued)																	
10/10-15	418	0.0	23.6	7.9	3.7		1.9	4.6				3.13	0.00	43	0.67		
10/10-15	419	2.0	23.1	7.8	5.8		0.9	6.3				3.26	0.71	47	0.82		
Survey Station 7																	
2/14-15	19	0.0	9.1		1.6	0.50						3.00	1.97	102			
2/14-15	20	1.0	9.2		1.5	0.52						3.20	0.00	63			
3/13-18	51	0.0	19.6	8.3	3.5							2.49	0.65	40			
3/15-18	52	1.5	18.8	8.1	3.0							1.29	1.45	37		0.27	0.00
3/15-18	53	2.5	17.9	7.7	3.0							1.68	1.45	75		0.57	0.00
7/18-14	306	0.0	31.0	8.0	4.6		2.0	5.5				1.52	0.71	20		0.47	0.58
7/18-14	307	2.0	30.5	8.0	4.5		1.3	0.8				1.49	0.77	32			
10/10-16	420	0.0	23.8	8.1	7.2		2.1	3.1				2.74	0.68	40	0.82		
10/10-16	421	1.5	24.0	8.1	5.8		0.0	2.4				0.36	0.32	47	0.78		
11/20-15	515	0.5	21.7	7.9	5.3		20.5	7.9	33.8		5.88	6.55		8	1.00		

* ± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - - -	- - - -	- - - -	- - - - ug-at/l	- - - -	- - - -	- - - -	- - - -	- - - -	mg-at/l	- - - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Survey Station 8																	
7/20-11	327	0.0	31.0	8.4	4.4		2.5	0.0				0.55	0.90	22			
7/20-11	328	2.5	30.5	8.2	4.2		2.4	0.6				0.39	0.36	22			
7/20-11	329	4.0	30.5	7.8	5.8		5.4	2.7				0.77	0.61	17			
10/11-11	428	0.0	23.5	8.1	7.8		1.9	1.8				1.39	0.48	13	0.74		
10/11-11	429	3.5	23.2	8.1	7.6		1.9	1.8				1.19	0.39	55	0.70		
Survey Station 9																	
7/20-12	327	0.0	30.5	8.4	4.2		6.0	0.0				1.23	0.55	33	0.89		
7/20-12	328	2.5	30.0	8.1	3.8		3.0	2.8				2.13	0.00	28	0.72		
10/11-12	430	0.0	23.8	8.1	7.8		3.1	0.0				0.94	0.61	23	0.68		
10/11-12	431	3.0	23.1	8.2	7.6		2.3	1.6				0.77	0.45	57	0.68		
10/11-12	432	4.0	23.1	8.1	7.5		0.3	0.4				1.07	1.00	67	0.70		

± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. $\frac{\text{mmhos}}{\text{cm}}$	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - -	- - -	- - -	- - -	μg-at/l	- - -	- - -	- - -	- - -	mg-at/l	- - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Survey Station 10																	
4/28-8	84	0.0	21.4	8.2	2.1		3.1	1.8				0.10		15			
4/28-8	85	1.5	21.4	8.0	2.5		1.3	1.3				0.23		25	2.36		
7/20-13	331	1.5	30.0		2.9		2.6	0.0				0.23	0.58	12	0.69		
10/11-13	434	0.0	23.6	8.3	2.3		5.6	1.5				0.84	0.77	30	0.56		
10/11-13	435	3.5	22.3	8.2	4.2		1.4	2.8				0.29	0.84	17	0.58		
Survey Station 11																	
10/11-14	436	0.0	23.3	7.8	7.6		1.2	1.3				1.07	0.45	30	0.70		
10/11-14	437	4.0	23.2	7.9	7.6		2.1	4.9				0.81	0.48	62			
Survey Station 12																	
4/28-11	88	0.0	22.0	7.9	3.8		0.0	0.2				0.45		37	0.58		

*± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. µmhos/cm	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							µg-at/l								mg-at/l		
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Survey Station 12 (Continued)																	
4/28-11	89	1.5	21.8	7.8	1.2		0.2	0.2				0.61		18	0.61		
10/11-15	438	0.0	23.9	7.7	6.5		1.0	0.7				0.58	0.26	70	0.75		
10/11-15	439	2.5	24.0	7.7	9.5		0.4	9.3				0.48	0.74	73			
Survey Station 13																	
10/11-17	443	0.0	23.0	7.8	9.9		1.4	6.9				1.16	1.19	68	0.85		
10/11-17	444	3.0	23.1	7.9	6.3		2.7	1.9				1.16	0.03	70	0.83		
10/11-17	445	5.0	23.0	7.9	6.9		14.4	11.6				1.03	0.45	70	0.79		
11/01-8	479	0.0		8.1	7.7		0.0	6.4	21.2	12.3	0.39	0.48	0.29	77	1.06	7.59	0.70
11/01-8	480	1.0		8.6	6.3		1.1	9.6	30.1	0.0	0.52	0.55	0.10	86	0.90	2.23	0.60
11/01-8	481	3.0		8.4	12.4		0.8	6.4	23.8	6.6	0.52	0.55	0.23	85	1.19	2.05	0.11
11/01-8	482	6.0		8.7	8.5		0.0	3.2	19.6	1.0	0.52	0.71	0.00	66	1.18	4.76	0.70
11/01-11	487	0.0	24.5	8.5	11.4		0.0	2.2	9.8	22.5	0.45	0.52	0.61	55			
11/01-11	488	1.0	24.5	8.5	10.8		0.6	0.0	22.9	13.7	0.52	0.71	0.19	72			

*± values refer to overall prevision estimates as discussed in the test. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. $\frac{mmhos}{cm}$	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - -	- - -	- - -	- - -	ug-at/l	- - -	- - -	- - -	- - -	mg-at/l	- - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Survey Station 13 (Continued)																	
11/01-11	489	3.0	24.5	8.6	9.7		0.2	1.1	24.3	16.6	0.48	0.81	0.00	72			
11/01-11	490	6.0	24.3	8.5	13.6		0.0	0.3	27.4	0.0	0.52	0.71	0.26	71			
11/01-14	491	0.0	23.5	8.4	9.4		0.0	0.1	21.5	6.9	0.55	0.71	0.16	73		7.87	0.00
11/01-14	492	1.0	23.2	8.6	11.0		0.9	0.0	23.8	3.7	0.48	0.65	0.16	83			
11/01-14	493	3.0	23.2	8.7	13.9		0.9	1.1	26.2	17.3	0.45	0.71	0.13	85		2.19	0.27
11/01-14	494	6.0	23.2	8.6	13.9		0.0	0.0	18.5	24.6	0.45	0.74	0.23	72		7.05	0.18
11/01-17	495	0.0	23.0	8.5	8.3		1.1	1.0	22.4	25.8	1.07	0.84	0.00	104	1.10	5.16	0.97
11/01-17	496	1.0	22.6	8.5	4.8		0.4	0.9	19.4	4.9	0.45	0.45	0.06	85	1.08	2.27	0.00
11/01-17	497	3.0	22.0	8.7	5.9		0.9	1.1	27.4	1.2	0.45	0.39	0.23	85	1.20	2.12	0.08
11/01-17	498	6.0	22.2	8.4	6.6		0.0	0.9	24.6	3.7	0.23	0.32	0.36	46	1.15	6.90	0.98
Survey Station 14																	
4/28-9	86	0.0	21.4	7.8	2.5	1.37	6.4	2.5				0.10		47			
10/11-18	446	0.0	24.0	7.8	7.9		4.1	0.6				0.55	0.52	68	0.70		
10/11-18	447	3.0	24.0	7.8	6.2		2.1	3.0				0.74	0.74	22			

*± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							µg-at/l								mg-at/l		
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Master Station 1																	
2/14-11	8	0.0	8.9	6.6	0.1	0.16						1.61	0.13	32			
2/14-11	9	1.0	8.8	6.5	0.1	0.16						1.65	0.94	50			
3/15-13	40	0.0	18.1	7.2	0.5		4.8	24.2	30.3	24.8		1.87	1.29	121	0.51	1.96	0.79
3/15-13	41	1.0	17.4	7.2	0.5		21.5	20.5	20.4	11.6		2.84	0.81	145		1.26	1.94
3/15-13	42	5.0	17.3	7.2	0.5		8.1	24.3	33.2	16.8		2.36	1.29	88	0.51	0.94	0.81
3/16-10	58	0.5	16.5	7.5	0.4		4.1	26.3	28.2	15.3	1.42	2.16	3.03	88	0.49	2.35	0.92
3/16-10	59	5.0	16.9	7.5	3.0		5.4	16.6	33.6	0.0	1.49	2.03	0.39	88		2.35	1.71
3/16-13	60	0.0	17.4	7.3	4.8		12.9	23.8	26.7	2.9	1.52	1.49	1.94	83	0.47		
3/16-13	61	1.0	16.8	7.4	0.4		4.9	22.8	31.9	12.4	1.45	2.03	0.06	92	0.48		
3/16-13	62	5.0	16.8	7.3	0.4		6.4	26.5	36.6	4.5	1.52	2.36	1.68	98	0.49		
6/20-9	222	0.0	29.2	7.5	2.3		5.8	7.4	27.3	4.8	0.90	1.23	0.29	43	0.63	0.58	0.22
6/20-9	223	0.0	29.2	7.6	2.2		1.1	0.1	27.4	13.6	0.16	0.45	0.97	12	0.57		
6/20-9	224	0.0	29.2	7.6	2.5		0.0	1.0	29.4	10.2	0.16	0.45	0.94	12	0.77		
6/20-9	225	2.0	28.6	7.4	2.4		0.5	1.4	30.1	4.2	0.19	0.48	0.68	12	0.58		
6/20-9	226	2.0	28.6	7.5	2.4		0.5	0.1	25.3	13.8	0.16	0.32	1.29	12	0.58	0.58	0.35
6/20-9	227	2.0	28.6	7.5	2.5		0.9	2.6	27.9	15.2		0.45	0.94	12			

± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. $\frac{mmhos}{cm}$	Cl^- g/1	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - - - -	- - - - -	- - - - -	- - - - -	ug-at/1	- - - - -	- - - - -	- - - - -	- - - - -	mg-at/1	- - - - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Master Station 1 (Continued)																	
6/20-9	228	5.0	28.7	7.5	2.5		9.8	1.3	16.0	7.9	0.97	1.10	0.36	48	0.64	0.84	0.23
6/20-9	229	5.0	28.7	7.5	2.2		3.5	2.1	23.2	5.1	0.52	0.74	0.58	28	0.56		
6/20-9	230	5.0	28.6	7.5	1.7		1.6	2.0	23.6	14.1	0.19	0.32	0.94	18	0.59		
6/20-9	231	0.8	29.0	7.6	2.6		1.5	1.4	22.8	8.4	0.13	0.32	1.03	17	0.59	0.86	0.10
6/20-15	232	0.0	30.2	8.0	2.3		0.0	0.8	20.9	14.6	0.06	0.26	0.94		0.59	0.60	0.15
6/20-15	233	0.0	30.2	8.0	2.3		0.1	0.7	30.8	4.0	0.06				0.56		
6/20-15	234	0.0	30.2	8.0	2.3		0.3	1.0	29.8	13.4	0.16	0.58	0.68		0.62		
6/20-15	235	2.0	29.6	8.0	2.4		0.0	0.4	23.0	15.1	0.06	0.29	1.03		0.55	0.44	0.41
6/20-15	236	2.0	29.6	8.0	2.4		1.6	1.1	23.8	12.4	0.71	0.81	0.32		0.58		
6/20-15	237	2.0	29.6	8.0	2.2		0.1	1.4	37.6	5.1	0.06				0.54		
6/20-15	238	5.0	29.0	7.5	1.6		1.0	1.9	31.3	5.1	0.16	0.32	0.84		0.59	0.65	0.13
6/20-15	239	5.0	28.9	7.5	2.0		4.1	0.6	28.6	6.0	0.58	0.81	0.23		0.62	0.74	0.23
6/20-15	240	5.0	29.0	7.5	1.5		3.9	1.8	26.3	9.7	0.42				0.38		
6/20-15	241	0.8	30.2	8.0	2.2		0.0	0.9	26.6	12.4	0.06	0.36	0.58	19	0.55	0.81	0.05
7/18-10	298	0.0	30.0	7.4	1.7		2.1	5.7	29.8	0.0	0.29	0.64	0.81	28	0.21	0.70	0.10
7/18-10	299	2.5	30.0	7.4	1.1		3.6	5.4	25.9	0.5	0.23	0.74	0.52	21	0.17	0.59	0.01

*± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures

Table VI. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							ug-at/l								mg-at/l		
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Master Station 1 (Continued)																	
7/18-10	300	5.0	30.0	7.3	1.8		1.8	5.1	25.8	10.4	0.32	0.68	0.84	28	0.21	0.78	0.09
10/09-9	396	0.0	21.0	7.3	2.3		1.1	1.2	29.2	14.0	0.81	0.90	0.87	53	0.29	0.45	0.18
10/09-9	397	0.5	20.8	7.3	2.2		0.3	1.1	28.3	12.8	0.90	0.87	0.81	53	0.43	1.31	0.00
10/09-9	398	1.5	20.3	7.4	2.2		0.3	1.9	35.6	5.8				53	0.43	0.80	0.05
10/09-9	399	5.0	21.0	7.3	2.2		0.6	2.8	20.1	18.8	1.10	1.45	0.94	50	0.52		
10/09-12	400	0.5	21.2	7.4	2.3		0.0	8.6	29.1	6.1	0.68	0.94	1.29	50	0.48	0.93	0.03
10/09-12	401	0.5	21.3	7.4	2.1		0.0	4.4	29.1	8.1	0.61	1.10	1.49	47	0.51	0.92	0.04
10/09-12	402	0.5	21.7	7.4	2.4		0.4	6.6	31.1	9.5	0.84	1.39	1.22	44	0.46	0.72	0.26
10/09-12	403	0.5	21.8	7.4	2.3		0.0	2.6	37.6	2.9	0.61	1.03	1.81	45	0.49		
10/10-11	411	0.0	22.0	7.3	2.7		0.4	2.8	13.6	0.0	0.71	0.45	1.19	56	0.52		
10/10-11	412	2.5	22.0	7.4	2.8		1.9	7.1	17.3	0.0	0.65	0.65	1.66	56	0.52		
10/10-11	413	5.0	22.1	7.4	3.0		0.8	7.0	21.3	0.0	0.68	0.68	1.61	50	0.52		
12/01-11	557	0.5	17.8	7.4	1.6		4.4	4.4	30.3	8.1	1.23	1.49	0.45	53	0.51	0.70	0.00
12/14-9	621	0.0	11.5	7.3	1.5		7.7	7.0	29.2		1.90	2.03	1.29	84		1.86	0.06
12/15-9	652	0.0	10.7	7.3	2.6		2.1	9.9	24.7	2.6	1.16	1.45	0.74	63		0.98	0.00
12/15-9	653	0.5	11.0	7.5	2.4		2.9	8.6	24.3	2.3	1.16	1.49	0.71	62		0.84	0.10

± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures

Table A1. (Continued)

1978 Mo/Day-H	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - -	- - -	- - -	- - -	μg-at/l	- - -	- - -	- - -	- - -	mg-at/l	- - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Master Station 1 (Continued)																	
12/15-9	654	2.0	11.0	7.6	2.9		4.1	8.2	27.1	0.0	1.16	1.42	0.52	59		0.88	0.13
12/15-9	655	10.0	11.2	7.6	2.6		1.0	9.6	30.6	0.0	1.07	1.32	1.03	54		0.75	0.17
12/15-14	595	0.0	11.9	7.5	2.7		4.8	12.3	27.8	0.0	1.55	1.84	0.36	82		0.70	0.16
12/15-14	656	10.0	11.8	7.4	2.6		3.8	10.8	30.1	0.0	1.03	1.36	0.77	64			
Master Station 2																	
2/14-16	21	0.0	8.0		3.9	1.24						1.55	0.00	87			
2/14-16	22	1.0	8.2		3.8	1.26						1.16	0.16	55			
3/15-19	54	0.0	18.8	9.0	3.9		18.1	4.6	0.0			1.55	0.71	115	0.58	1.98	1.10
3/15-19	55	1.5	15.4	8.2	2.9		14.8	15.1	24.8	2.0		1.74	1.13	108	0.68	2.07	0.69
3/15-19	56	4.0	15.1	8.0	3.1		0.0	3.1	30.6	18.4		0.71	1.39	68	0.73	1.89	1.35
4/25-9	63	0.0	23.8	8.1	5.0		1.7	2.3	23.1	7.5	0.39	0.52	0.90	40	0.86		
4/25-9	64	2.0	22.9	8.1	5.4		1.2	0.2	26.9	7.1	0.26	0.42	0.74	37	0.91		

*± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - - - - - - - - - ug-at/l								- - - mg-at/l - - -		
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
							Master Station 2 (Continued)										
4/25-9	65	3.5	22.7	8.1	5.2		1.4	0.1	11.2	20.1	0.06	0.19	1.45	30	0.98	0.85	0.66
5/23-11	136	0.0	28.0	8.9	3.2	0.98	2.4	0.8	30.4	4.0				42		0.61	0.38
5/23-11	137	0.0	28.4	8.8	3.3		4.1	0.7	23.6	1.1							
5/23-11	138	0.0	28.0	8.8	3.3		0.0	1.7	32.3	1.7				17			
5/23-11	139	1.0	27.3	8.9	3.3		2.1	0.6	43.5	0.0	0.26	0.61	0.48			0.15	0.03
5/23-11	140	1.0	27.2	8.9	3.2	0.97	1.1	1.6	27.8	16.0	0.06	0.23	1.13	30			
5/23-11	141	1.0	27.3	8.9	3.2		0.7	0.4	29.3	0.6	0.19	0.55	0.74				
5/23-11	142	3.0	27.4	8.7	3.3	0.96	0.1	1.3	27.6	4.0	0.03	0.16	1.74	25		0.74	0.14
5/23-11	143	3.0	27.3	8.7	3.3		3.2	0.0	29.1	0.0							
5/23-11	144	3.0	27.4	8.7	[illegible]		3.1	2.8	13.0	24.9	0.06	0.39	1.19				
5/23-11	145	4.0	27.2	7.8	[illegible]		3.7	0.0	23.1	6.0	0.03	0.19	0.48	30		0.76	0.24
5/23-14	146	0.0	29.7	8.9	3.4		1.3	0.0	15.5	11.7	0.45	0.77	0.16			0.51	0.00
5/23-14	147	0.0	29.8	8.9	3.4	1.04	0.8	2.0	25.2	11.1	0.19	0.74	0.06	20			
5/23-14	148	0.0	29.7	8.9	3.4		3.4	1.3	20.7	17.6	0.52	0.81	0.23				
5/23-14	149	1.0	28.2	9.0	3.3		1.3	0.4	5.3	22.7	0.81	1.29	0.13			0.10	0.12

± values refer to overall precision estimates as discussed in the test. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. $\frac{mmhos}{cm}$	Cl^- g/1	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							ug-at/l								mg-at/l		
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Master Station 2 (Continued)																	
5/23-14	150	1.0	28.2	9.0	2.6		3.4	1.6			0.65	0.97	0.13	35			
5/23-14	151	1.0	28.2	9.0	3.0		1.0	3.0	6.5	3.1	0.16	0.16	0.45	13			
5/23-14	152	3.0	27.0	8.7	2.2		0.9	0.9	13.8	3.6	0.29	0.39	0.39	12		0.03	0.21
5/23-14	153	3.0	27.0	8.7	3.3		0.9	0.3	10.1	10.9	0.23	0.36	0.48	13			
5/23-14	154	3.0	27.0	8.7	3.1	0.93	2.0	1.4	7.9	1.5	0.16	0.16	0.32	12			
5/23-14	155	4.0	26.0	7.8	4.0	1.22	2.7	4.4	20.1	12.7	0.03	0.81	0.00	35		0.09	0.19
7/18-12	303	0.0	31.0	8.4	3.6		0.6	0.5	24.8	22.1	0.77	0.87	0.00	12	0.63	0.48	0.00
7/18-12	304	3.0	30.5	8.4	3.7		0.9	0.7	21.6	16.6	0.39	0.45	0.36	12	0.66	0.44	0.19
7/18-12	305	4.0	30.0	8.2	3.9		4.4	2.1	29.1	8.6	1.00	0.96	0.06	41	0.64	0.57	0.04
9/19-9	358	0.0	29.0	7.8	5.2		1.9	2.9	29.6	7.0	1.03	1.48	0.13	48	0.98		
9/19-9	359	0.8	29.2	7.8	4.3		0.6	1.1	30.9	0.6	0.45	0.45	0.58	42	1.48	1.63	0.09
9/19-9	360	2.5	28.8	7.8	4.8		0.2	1.6	32.4	4.1	0.45	0.65	0.74	12	1.16	1.82	0.15
9/19-9	361	4.0	29.0	7.4	5.2		0.0	1.0	24.5	6.4	0.45	0.71	0.61	28	1.17	2.23	0.00
9/19-13	362	2.5	29.2	8.0	5.0		0.0	0.7	21.6	7.6	0.26	0.65	0.71	22	1.89		
9/19-13	363	2.5	29.3	8.0	5.6		1.7	0.6	13.5		0.39	0.68		34			
9/19-13	364	2.5	29.2	8.0	5.3		0.1	0.2	15.6	17.5	0.19	0.32	1.19	13	1.09		

± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/1	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							ug-at/1								mg-at/1		
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Master Station 2 (Continued)																	
9/19-13	365	2.5	29.3	8.0	4.8		0.7	1.6	13.3		0.45	0.58	0.45	40	1.32		
9/19-16	366	0.0	29.4	8.1	5.8		1.0	0.0	21.3	8.6	0.61	0.84	0.42	39	1.10		
9/19-16	367	0.5	29.5	8.0	5.8		1.9	1.4	25.0	1.1	0.42	0.58	0.65	38	1.03	1.01	0.06
9/19-16	368	2.5	29.5	8.1	4.2		0.0	2.0	25.1	0.6	0.42	0.61	0.87	36	0.97	0.87	0.00
9/19-16	369	4.0	29.3	7.8	2.7		0.2	2.1	12.9		0.26	0.39		17	1.46	0.69	0.00
10/10-17	422	0.0	23.0	8.3	5.0		10.3	1.8	17.3	3.1	0.90	1.03	0.61	50	0.61		
10/10-17	423	1.5	22.9	8.2	5.7		12.0	1.0	15.1	13.1	0.87	1.03	1.68	53	0.81		
10/10-17	424	4.0	23.1	8.4	6.2		21.1	0.0	10.4	25.4	0.90	1.03	4.58	37	0.55		
10/30-10	458	0.0	23.5	8.2	3.2		0.0	0.0	23.3	2.1	0.61	0.90	0.03	33			
10/30-10	459	1.0	22.2	8.2	3.8		0.0	0.0	27.0	0.0	0.81	1.16	0.36	55			
10/30-10	460	2.5	22.2	8.1	6.7		0.0	3.2	26.8	3.1	1.29	1.29	0.48	83	0.81	1.53	0.00
10/30-10	461	4.0	22.1	8.1	6.9		0.5	1.6	16.5		1.10	1.36		69	0.92	2.45	0.07
10/30-15	462	0.0	23.0	8.3	6.5		0.5	1.8	23.6	7.6	1.16	1.36	1.45	82	0.78	0.90	0.06
10/30-15	463	1.0	22.8	8.3	6.5		0.0	0.0	27.6	5.7	0.90	0.87	0.97	70	0.82		
10/30-15	464	2.5	22.8	8.4	6.1		0.0	1.2	28.1	3.1	0.97	1.13	1.49	72	0.84	0.82	0.00

± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - - - - - - - - - - - ug-at/l - - - - - - - - - - - -								- - - mg-at/l - - -		
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Master Station 2 (Continued)																	
10/30-15	465	4.0	22.5	8.4	7.2		0.0	1.0	23.1	4.3	0.90	1.00	1.45	60	0.82	1.14	0.16
11/10-11	510	0.5	21.2	7.7	3.6		0.0	0.4	13.7	1.7	0.58	0.71	0.68	51	0.79		
Master Station 3																	
4/25-11	66	0.0	23.8	8.2	3.6		0.8	0.0	21.3	9.0	0.52	0.71	0.68	33	0.61	0.54	0.02
4/25-11	67	1.0	23.1	8.1	4.0		1.9	0.0	22.6	8.4	0.58	0.84	1.16	35	0.87	0.52	0.08
4/25-11	68	9.0	23.4	7.7	17.8		19.8	0.0	28.6	0.0	1.58	2.00	0.48	42	1.61	0.19	0.07
4/26-11	69	0.0	21.2	8.1	4.0		1.6	2.4	21.5	29.3	1.19	1.32	1.58	33	0.87	0.46	0.12
4/26-11	70	1.0	21.0	8.1	3.1		0.0	2.6	27.2	8.6	1.00	1.23	1.90	23	0.88	0.33	0.09
4/26-14	71	0.0	21.5	8.1	2.9		0.0	1.4	25.1	19.3	0.65	0.84	2.39	14	0.85	0.20	0.48
4/26-14	72	1.0	21.2	8.1	3.4		0.0	2.2	24.6		0.84	1.26		20	1.29	0.35	
6/22-10	274	0.0	29.2	8.2	3.1		0.3	1.0	26.6	2.9	0.90				0.81	0.61	0.11
6/22-10	275	0.0	29.0	8.2	3.9		0.8	1.7	32.3	0.0	0.94	1.16	0.77				
6/22-10	276	0.0	29.2	8.2	4.6		0.8	1.3	26.8	9.2	1.07	1.29	0.68				

*± values refer to overall precision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	$NH_3 + NH_4^+$	$NO_2^- + NO_3^-$	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - - - -	- - - - -	- - - - -	- - - - -	ug-at/l	- - - - -	- - - - -	- - - - -	- - - -	mg-at/l	- - - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
									Master Station 3 (Continued)								
6/22-10	277	3.0	29.1	8.0	3.5		0.6	2.5	21.3	7.6	1.16	1.32	0.87			0.54	0.12
6/22-10	278	3.0	29.2	8.0	4.3		2.4	0.9	22.6	14.0	1.45	1.58	0.19				
6/22-10	279	3.0	29.2	8.1	4.8		0.3	2.3	24.8	11.9	1.03	1.36	0.74				
6/22-10	280	10.0	29.3	7.6	11.2		28.1	13.1	10.1	6.9	2.97				1.43	0.44	
6/22-10	281	10.0	29.2	7.7	16.8		23.1	0.8	16.4	0.0	3.03	2.91	1.39				
6/22-10	282	10.0	28.6	7.5	15.4		23.4	2.6	16.0	1.7	3.00	3.03	0.48				
6/22-10	283	1.0	29.4	8.1	4.4		1.1	6.6	31.3	1.1	0.74	1.00	0.65	21	0.66	0.75	
6/22-16	284	0.0	30.2	8.3	6.0		2.1	2.2	26.0	7.1	1.07	1.23	1.39		1.00	0.97	
6/22-16	285	0.0	30.2	8.3	3.6		1.1	1.8	21.4	6.7	1.16	1.42	0.00				
6/22-16	286	0.0	30.2	8.3	6.1		1.1	3.2	27.3	7.6	1.19	1.68	3.58				
6/22-16	287	3.0	30.0	8.2	6.7		1.3	3.9	18.8	11.2	0.81	0.94	1.07		0.92	0.61	
6/22-16	288	3.0	30.0	8.2	6.8		0.2	3.0	21.3	9.9	1.03	1.19	0.77			0.60	0.06
6/22-16	289	3.0	30.2	8.2	7.5		3.8	6.1	25.8	10.1	1.10	1.32	0.90			0.56	0.00
6/22-16	290	10.0	29.9	7.6	13.0		40.2	0.0	3.4	3.0	4.71	4.46	1.10		1.38	0.50	0.14
6/22-16	291	10.0	30.0	7.6	13.2		29.1	0.0	19.1	3.2	3.81	3.55	0.84			0.52	0.13
6/22-16	292	10.0	30.0	7.6	12.7		33.7	0.0	6.7	2.8	4.52	6.46	0.16			0.48	0.21

*± values refer to overall precision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - -	- - -	- - -	µg-at/l	- - -	- - -	- - -	- - -	- - -	mg-at/l	- - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
							Master Station 3 (Continued)										
6/22-16	293	1.0	31.8	8.2	7.1		1.5	2.8	16.8	8.9	0.97	1.36	1.07	25	0.99	0.45	0.18
7/20-10	324	0.0	31.0	8.2	6.7		4.6	0.0	12.6	11.4	0.65	0.87	0.77	31	0.94	1.26	0.00
7/20-10	325	2.5	30.5	8.2	5.4		3.9	1.2	13.3	10.2	0.65	0.87	0.87	31	0.93	1.67	0.00
7/20-10	326	9.0	30.5	8.0	12.1		14.5	3.1	16.8	2.0	1.39	1.65	0.71	47			
9/21-12	384	0.0	29.0	8.3	4.7		1.0	4.6	18.7	8.1	3.20	3.33	0.48	53	1.64	0.58	0.23
9/21-12	385	1.0	29.0	8.1	5.3		1.0	6.6	20.0	4.1	3.23	3.58	0.03	52	1.28	0.66	0.23
9/21-12	386	3.0	29.0	8.0	5.1		1.1	6.6	23.3	4.4	3.33	3.78	0.71	53	1.99	0.66	0.11
9/12-12	387	9.0	29.7	7.5	4.7		0.0	15.9	21.6	0.0	2.74	3.16	0.00	51	1.96	0.53	0.21
9/21-15	388	3.0	29.1	8.2	5.1		1.0	7.5	25.6	5.4	3.49	4.04	0.48	52	1.71	0.73	0.00
9/21-15	389	3.0	29.2	8.1	5.3		0.9	8.4	28.2	5.9	3.58	4.04	0.52	52	1.57	0.65	0.14
9/21-15	390	3.0	29.1	8.2	6.0		1.6	17.1	12.9	7.6	3.78	3.65	0.58	59	1.58	0.61	0.09
9/21-15	391	3.0	29.0	7.8	5.3		0.3	10.7	36.0	3.2	2.78	3.94	0.55	50	1.64	0.60	0.02
9/21-17	392	0.0	29.2	8.1	4.7					6.8		4.20	0.74	51	1.32	0.74	0.00
9/21-17	393	1.0	29.1	8.2	4.7		0.8	1.4	16.6	12.4	2.94	3.20	1.84	46	1.42	0.71	0.43
9/21-17	394	3.0	29.0	8.0	4.7		3.1	11.5	27.9	1.2	3.91	4.13	0.94	52		0.65	0.05
9/21-17	395	5.0	29.3	7.4	19.5		2.5	16.3	24.2	1.9	3.65	3.75	0.36	49	1.94	0.61	0.00

* ± values refer to overall prevision estimates as discussed in the test. These estimates include both field and laboratory procedures

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							μg-at/l								mg-at/l		
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
								Master Station (Continued)									
10/11-11	425	0.0	23.2	8.2	5.2		0.1	1.2	19.8	0.6	0.94	1.13	0.32	40	0.57		
10/11-11	426	3.5	23.9	7.7	12.1		0.2	6.6	25.3	8.0	1.90	2.07	0.55	55	1.07	0.70	0.03
10/11-11	427	8.0	24.2	7.7	12.8		3.4	6.6	22.1	8.0	1.90	2.23	0.36	50	1.10	0.51	0.05
11/03-10	499	0.0	23.1	8.9	6.9		1.1	0.0	22.5	8.2	1.36	1.61	0.61	53		0.87	0.00
11/03-10	500	2.0	22.7	8.8	7.1		3.3	1.4	20.8	14.1	1.65	1.94	0.13	76	0.89	0.91	0.00
11/03-10	501	5.0	22.6	8.8	7.0		2.4	2.6	21.8	4.1	1.42	1.55	0.29	53	1.16	1.02	0.15
11/03-10	502	10.0	22.1	8.2	20.8		9.1	5.7	37.2	0.0	1.81	1.97	0.77	47	1.64	0.70	0.00
11/03-15	503	0.0	23.5	8.9	6.1		1.1	0.0	21.3	5.4	1.42	1.58	0.36	52	0.87	0.92	0.00
11/03-15	504	2.0	22.8	8.8	6.6		1.1	0.0	18.3	13.6	1.19	1.39	0.77	51	0.83	0.56	0.24
11/03-15	507	4.0	22.8	8.9	7.7		2.7	5.1	20.1	11.4	1.58	1.79	0.00	77	0.91	0.66	0.02
11/03-15	505	5.0	22.5	8.3	8.8		6.1	0.5	19.3	0.0	1.49	1.49	0.00	45	1.38	0.62	0.00
11/03-15	506	10.0	22.7	8.1	21.2		8.4	2.3	17.9	7.9	1.74	1.87	0.29	41	1.58	0.55	0.10
11/20-13	512	0.5	21.0	8.2	7.5		0.2	0.9	21.3	3.6	0.87	1.29	0.61	12	0.83		
11/20-14	513	0.5	21.0	8.1	6.4		0.0	0.9	17.4	6.4	0.77	1.03	0.90	11	0.82		

± values refer to overall precision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. $\frac{mmhos}{cm}$	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							µg-at/l								mg-at/l		
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Master Station 4																	
5/24-10	156	0.0	28.0	7.8	2.8		4.4	5.6	2.1	7.8	0.97	0.97	0.00	78		0.95	0.27
5/24-10	157	0.0	27.2	7.9	2.7		5.0	8.6	6.9	0.6	0.81	0.94	0.39	68			
5/24-10	158	0.0	27.6	7.9	2.8		1.4	4.9	4.7	8.6	0.13	0.55	0.45	50			
5/24-10	159	1.5	27.7	7.9	2.8		3.7	5.3	10.6	0.4	0.68	0.81	0.36	72		1.02	
5/24-10	160	1.5	27.4	7.8	2.9	0.90											
5/24-10	161	1.5	27.5	7.8	2.9		1.6	4.7	3.9	5.8	0.19	0.42	0.90	48			
5/24-10	162	8.0	26.8	7.8	2.7	0.86	4.5	2.3	26.7	2.6	0.10	0.74	0.68	52		0.19	0.29
5/24-10	166	8.0	27.0	7.8	2.8		2.1	6.2	5.4	2.0	0.26	0.32	0.87	50			
5/24-10	167	8.0	27.2	7.8	2.7		3.6	4.1	3.6	3.8	0.26	0.29	0.97	65			
5/24-10	168	0.5	27.2	7.9	3.0		4.6	6.2	7.4	1.3	1.03	1.16	0.26	65			
5/24-15	169	0.0	26.6	7.1	1.4		3.7	12.1	4.8	0.6	0.55	0.71	1.39	52		0.55	0.03
5/24-15	170	0.0	26.6	7.1	1.4		4.2	11.6	22.8	5.9	0.39	0.87	0.97	80			
5/24-15	171	0.0	26.5	7.1	1.5		6.7	10.1	24.1	2.1	1.07	1.26	0.55	67			
5/24-15	172	1.5	26.4	7.1	1.4		3.5	12.0	6.7	3.1	0.55	0.58	1.42	62		0.86	0.40
5/24-15	173	1.5	26.2	7.1	1.4		3.0	12.8	32.1	2.9	0.16	0.45	1.42	57			
5/24-15	174	1.5	26.0	7.0	1.5	0.48	6.1	15.1	29.0	2.2	0.13	1.03	0.58	77			

± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. $\frac{mmhos}{cm}$	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - - -	- - - -	- - - -	- - - -	µg-at/l	- - - -	- - - -	- - - -	- - - -	mg-at/l	- - - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
								Master Station 4 (Continued)									
5/24-15	175	8.0	26.6	7.1	1.5		6.6	9.9						58			
5/24-15	176	8.0	26.2	7.1	1.7	0.52	5.1	10.1	31.8	4.7	0.16	0.48	1.78	72		0.85	1.04
5/24-15	177	8.0	26.2	7.1	1.3	0.36	5.4	9.9	28.1	2.5	0.52	0.84	1.94	128			
5/24-15	178	0.5	26.8	7.4	1.5		1.6	10.6	21.1	13.1	0.26	0.48	1.10	87			
9/20-9	370	0.0	29.5	7.7	12.6		0.2	1.6	26.4	6.4	0.58	0.61	1.07	77	1.10		
9/20-9	371	1.0	29.2	7.6	12.8		0.1	1.4	25.2	5.7	0.65	0.77	0.87	78	1.05		
9/20-9	372	3.0	29.3	7.5	12.1		0.3	3.7	25.8	3.6	0.68	0.74	1.58	77	1.01		
9/20-9	373	10.0	29.3	7.6	13.4		0.9	2.4	23.8	8.9	0.74	0.68	1.65	77	1.08	0.54	0.00
9/20-13	374	1.0	29.5	7.7	12.5		0.4	2.5	22.4	9.5	0.58	1.07	0.68	70			
9/20-13	375	1.0	29.4	7.7	12.1		0.3	1.3	20.0	11.4	0.55	0.90	1.13	67			
9/20-13	376	1.0	29.5	7.7			0.8	1.1	7.2	3.4	0.48	0.84	0.61				
9/20-13	377	1.0	29.5	7.7			2.5	0.0	2.1	14.9	0.26	0.48	1.00			0.57	0.06
9/20-15	378	0.0	29.8	7.8			1.4	1.1	20.3	0.0	0.42	0.84	0.52		0.97		
9/20-15	379	1.0	29.7	7.8			0.6	0.4	10.9	4.6	0.39	0.61	0.58		0.93		
9/20-15	380	3.0	29.6	7.8			0.8	0.4	7.2	9.1	0.48	0.81	0.52		0.96	0.60	0.00
9/20-15	381	10.0	29.7	7.7			0.8	0.8	16.3	1.1	0.36	0.74	0.84		1.01	0.59	0.01

*± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A1. (Continued)

1978 Mo/Day-Hr	Sample #	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							- - -	- - -	- - -	- - -	ug-at/l	- - -	- - -	- - -	- - -	mg-at/l	- - -
					±0.4	±0.02	±1.5	±2.4	±4.4	±6.2	±0.26	±0.32	±0.34	±12	±0.07	±0.06	±0.06
Master Station 4 (Continued)																	
10/11-16	440	0.0	23.0	7.8	12.6		0.0	2.1	11.6	0.0	0.45	0.65	0.84	77	0.87	0.52	0.02
10/11-16	441	2.0	23.2	7.9	13.4		0.0	0.0	24.6	4.6	0.48	0.71	0.16	71	0.87		
10/11-16	442	10.0	22.9	7.9	14.5		0.6	1.2	12.8	0.0	0.39	0.45	1.00	65	0.94	0.64	0.19
10/31-9	466	0.0	22.0	8.0	11.1		0.0	0.0	31.3	5.6	0.45	0.39	0.61	67	1.14		
10/31-9	467	1.5	22.0	8.0	15.8		0.6	0.0			0.65	0.77		72	1.04		
10/31-9	468	4.5	22.1	7.9	14.9		2.2	1.4	30.5	3.9	1.07	0.74	0.42	88	1.02	0.81	0.00
10/31-9	469	10.0	22.3	7.9	11.1		0.6	0.8	31.0	3.9	0.58	0.55	1.07	73	0.95	0.59	0.20
11/21-8	470	0.0	22.0	7.8											1.13		
11/21-8	471	5.0	22.0	7.8											1.05		

* ± values refer to overall prevision estimates as discussed in the text. These estimates include both field and laboratory procedures.

Table A2. Depth and Time Averaged Chemical Data from Lake Pontchartrain, LA During 1978*

Sta.	1978 Date	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl- g/1	$NH_3 + NH_4^+$	$NO_2^- + NO_3^-$	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg C	Dis Org. C	Undis Org. C
							ug-at/l								ug-at/l		
S1	2/14	0.0-1.5	7.8	7.2	2.4 ±0.0	0.81 ±0.03						0.87 ±0.20	0.94 ±0.07	30 ±16			
S1	3/15	0.0-1.5	16.9	7.3	3.3 ±1.7							0.97 ±0.88	1.42 ±0.26	43 ±5			
S1	7/18	2.5	30.0	7.4	2.0		3.0	1.4				0.42	1.29			0.44	0.30
S1	10/10	0.0-1.5	21.0	7.3	2.1 ±0.3		2.3 ±4.1	2.4 ±1.3				1.38 ±0.85	0.74 ±1.45	59 ±1	0.47		
S2	2/14	0.0-15	7.6	6.7	2.7 ±0.0	0.86 ±0.03						0.71 ±0.51	1.18 ±0.28	33 ±21			
S2	3/15	0.0-2.0	17.6	8.4	2.8 ±2.7							1.26 ±0.57	0.52 ±1.01	46 ±5			
S2	7/18	0.0-2.5	30.0	7.8	2.5 ±0.0		3.6 ±7.0	0.8 ±1.6				1.17 ±1.26	0.63 ±1.23	34 ±56	0.56 ±0.09	0.57 ±0.11	0.20 ±0.07
S2	9/21	0.0-1.0	29.0	7.7	2.6 ±0.1		0.5 ±0.3	1.0 ±0.8				0.42 ±0.31	1.07 ±0.50	38 ±10	0.98 ±0.07		
S2	10/10	0.0-3.0	21.4	7.6	2.9 ±1.4		0.5 ±0.9	2.2 ±3.5				0.50 ±0.22	0.67 ±0.54	38 ±11	0.57 ±0.02		
S3	2/14	0.0-3.0	8.1	6.5	1.4 ±0.1	0.48 ±0.02						1.40 ±0.35	0.98 ±0.33	53 ±19			

*± values represent 95% of confidence intervals equivalent to ±1.96 times standard error of the mean value. The absence of a ± value means only one analysis was performed.

Table 32. (Continued)

Sta.	1978 Date	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl^- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg. C	Dis. Org. C	Undis. Org. C
							µg-at/l								mg-at/l		
S3	3/15	0.0-3.0	17.2	7.4	3.7 ±0.6							0.93 ±1.23	3.84 ±4.53	34 ±12	0.62 ±0.12		
S3	7/18	0.0-3.0	30.0	8.1	2.7 ±0.3		2.2 ±1.1	0.6 ±0.1				0.16 ±0.00	1.20 ±0.25	7	0.43 ±0.04	0.46 ±0.01	0.40 ±0.05
S3	10/10	0.0-3.0	22.1	7.4	2.7 ±0.1		0.9 ±1.0	0.9 ±1.2				0.58 ±0.49	0.49 ±0.46	41 ±6	0.50		
S3	12/01	0.5	17.8	7.7	5.5		1.4	1.6	24.7	8.1	0.55	0.71	0.55	49	0.77	0.52	0.00
S3	12/14	0.0-2.0	12.0	7.5	4.4 ±1.2		0.5 ±1.0	3.7 ±1.5	27.5 ±2.5	7.5 ±2.2	0.59 ±0.44	0.81 ±0.44	0.94 ±0.13	14 ±5		1.87 ±1.01	0.11 ±0.02
S4	2/14	0.0-1.0	8.2	7.0	1.4 ±0.0	0.54 ±0.10						1.44 ±0.28	0.94 ±0.75	67 ±23			
S4	3/15	0.0-2.5	17.6	8.6	4.6 ±1.2							0.41 ±0.34	3.60 ±3.70	10 ±4			
S4	10/10	0.0-2.0	22.3	7.7	3.9 ±0.0		0.6 ±0.4	2.0 ±1.2				0.69 ±0.16	0.70 ±0.23	32 ±6	[illegible] ±0.13		
S5	2/14	0.0-3.0	8.6	7.0	2.6 ±0.1	0.84 ±0.06						1.01 ±0.36	0.34 ±0.39	43 ±43			
S5	3/14 & 15	0.0-2.5	17.4	8.5	3.9 ±0.3		3.3 ±1.2	1.8 ±0.9	31.0 ±4.8	3.2 ±2.0		0.18 ±0.07	1.98 ±0.43	35 ±5	0.63 ±0.04	2.02 ±0.71	0.86 ±0.35

* ± values represent 95% of confidence intervals equivalent to ±1.96 times standard error of the mean value. The absence of a ± value means only one analysis was performed.

Table A2. (continued)

Sta.	1978 Date	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg C	Dis Org. C	Undis Org. C
							µg-at/l								mg-at/l		
S5	7/18	0.0-3.5	30.3	8.1	3.5 ±0.0		8.8 ±8.8	0.0 ±0.0				0.84 ±0.94	1.21 ±0.35	21 ±22			
S5	10/10	0.0-3.5	23.5	7.9	5.3 ±0.4		1.0 ±1.2	0.3 ±0.5				1.10 ±0.06	0.52 ±0.13	42 ±3	0.70 ±0.02		
S5	12/01	0.5	17.7	7.8	3.4		2.1	1.4	27.2	0.0	0.61	0.90	0.00	17	0.67	0.62	0.00
S5	12/15	0.0	11.2	8.1	5.5		0.0	2.2	23.5	6.4	0.58	0.84	0.65	52			
S6	2/14- 15	0.0-2.0	15.4	7.6	2.0 ±0.8							3.15 ±1.48	1.03 ±0.90	61 ±13	0.65 ±0.03	0.18	0.10
S6	7/18	0.0-2.0	31.0	7.8	5.3 ±0.1		5.6 ±4.2	1.5 ±2.8				2.75 ±0.64	0.78 ±1.01	48 ±44			
S6	10/10	0.0-2.0	23.4	7.9	4.8 ±2.1		1.4 ±1.0	5.5 ±1.7				3.20 ±0.13	0.36 ±0.70	45 ±4	0.75 ±0.15		
S7	2/14	0.0-1.0	9.2		1.6 ±0.1	0.51 ±0.02						3.10 ±0.02	0.99 ±1.93	83 ±38			
S7	3/15	0.0-2.5	18.8	8.0	3.2 ±0.3							1.82 ±0.69	1.18 ±0.52	51 ±24		0.42 ±0.29	0.00 ±0.00
S7	7/18	0.0-2.0	30.8	8.0	4.6 ±0.1		1.7 ±0.7	3.2 ±4.6				1.51 ±0.03	0.74 ±0.06	26 ±12		0.47	0.58

*± values represent 95% of confidence intervals equivalent to ±1.96 times standard error of the mean value. The absence of a ± value means only one analysis was performed.

Table A2. (Continued)

Sta.	1978 Date	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg C	Dis Org. C	Undis Org. C
							µg-at/l								mg-at/l		
S10	10/11	0.0-3.5	23.0	8.3	3.3 ±1.9		3.5 ±4.1	2.2 ±1.3				0.57 ±0.54	0.81 ±0.07	24 ±13	0.57 ±0.02		
S11	10/11	0.0	23.3	7.9	7.6		1.2	1.3				1.07	0.45	30	0.70		
S11	10/11	4.0	23.2	7.9	7.6		2.1	4.9				0.81	0.48	62			
S12	4/28	0.0-1.5	21.9	7.9	2.5 ±2.6		0.1 ±0.2	0.2 ±0.0				0.53 ±0.16		28 ±17	0.60 ±0.03		
S12	10/11	0.0-2.5	24.0	7.7	8.0 ±2.9		0.7 ±0.6	5.0 ±8.4				0.53 ±0.10	0.50 ±0.47	72 ±3	0.75		
S13	10/11	0.3-3.0	23.1	7.9	8.1 ±3.5		2.1 ±1.3	4.4 ±4.9				1.16 ±0.00	0.61 ±1.14	69 ±2	0.84 ±0.02		
S13	10/11	5.0	23.0	7.9	6.9		14.4	11.6				1.03	0.45	70	0.79		
S13	11/01	0.0-3.0	23.4	8.5	9.3 ±1.6		0.6 ±0.3	2.5 ±1.8	22.8 ±2.8	11.0 ±4.8	0.53 ±0.10	0.61 ±0.08	0.18 ±0.09	80 ±7	1.09 ±0.09	3.94 ±1.77	0.27 ±0.26
S13	11/01	6.0	23.2	8.6	10.7 ±3.6		0.0 ±0.0	1.1 ±1.4	22.5 ±4.1	7.3 ±11.4	0.43 ±0.13	0.62 ±0.20	0.21 ±0.15	64 ±12	1.17 ±0.03	6.24 ±1.45	0.62 ±0.45
S14	4/28	0.0	21.4	7.8	2.5	1.37	6.4	2.5				0.10		47			

*± values represent 95% of confidence intervals equivalent to ±1.96 times standard error of the mean value. The absence of a ± value means only one analysis was performed.

Table A2. (Continued)

Sta.	1978 Date	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg C	Dis Org. C	Undis Org. C
							μg-at/l								mg-at/l		
S7	10/10	0.0-15	23.9	8.1	6.5 ±1.4		1.1 ±2.1	2.8 ±0.7				1.55 ±2.33	0.50 ±0.35	44 ±7	0.80 ±0.04		
S7	11/20	0.5	21.7	7.9	5.3		20.5	7.9	33.8		5.88	6.55		8	1.00		
S8	7/20	0.0-2.5	30.8	8.3	4.3 ±0.2		2.5 ±0.1	0.3 ±0.6				0.47 ±0.16	0.63 ±0.53	22 ±0			
S8	7/20	4.0	30.5	7.8	5.8		5.4	2.7				0.77	0.61	17			
S8	10/11	0.0-3.5	23.4	8.1	7.7 ±0.2		1.9 ±0.0	1.8 ±0.0				1.29 ±0.20	0.44 ±0.09	34 ±41	0.72 ±0.04		
S9	7/20	0.0-2.5	30.3	8.3	4.0 ±0.4		4.5 ±2.9	1.4 ±2.7				1.68 ±0.88	0.28 ±0.54	31 ±5	0.81 ±0.17		
S9	10/11	0.0-3.0	23.5	8.2	7.7 ±0.2		2.7 ±0.8	0.8 ±1.6				0.86 ±0.17	0.53 ±0.16	40 ±33	0.68 ±0.00		
S9	10/11	4.0	23.1	8.1	7.5		0.3	0.4				1.07	1.00	67	0.70		
S10	4/28	0.0-1.5	21.4	8.1	2.3 ±0.4		2.2 ±1.8	1.6 ±0.5				0.17 ±0.13		20 ±10	2.36		
S10	7/20	1.5	30.0		2.9		2.6	0.0				0.23	0.58	12	0.69		

* ± values represent 95% of confidence intervals equivalent to ±1.96 times standard error of the mean value. The absence of a ± value means only one analysis was performed.

Table A2. (continued)

Sta.	1978 Date	Depth m.	Water Temp. °C	pH	Cond. $\frac{mmhos}{cm}$	Cl- g/1	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg C	Dis Org. C	Undis Org. C
							ug-at/1								ug-at/1		
S14	10/11	0.0-3.0	24.0	7.8	7.1 ±1.7		3.1 ±2.0	1.8 ±2.4				0.65 ±0.19	0.63 ±0.22	45 ±45	0.70		
M1	2/14	0.0-1.0	8.9	6.6	0.1 ±0.0	0.16 ±0.00						1.63 ±0.04	0.54 ±0.79	41 ±18			
M1	3/15& 16	0.0-1.0	17.2	7.3	1.3 ±1.7		9.6 ±6.6	23.5 ±1.9	27.5 ±3.9	13.4 ±6.9	1.46 ±0.06	2.08 ±0.43	1.43 ±0.99	106 ±23	0.49 ±0.02	1.86 ±0.63	1.22 ±0.71
M1	3/15& 16	5.0	17.0	7.3	1.3 ±1.7		6.6 ±1.5	22.5 ±5.9	34.5 ±2.1	7.1 ±9.8	1.51 ±0.03	2.25 ±0.22	1.12 ±0.75	91 ±7	0.50 ±0.02	1.65 ±1.38	1.26 ±0.88
M1	6/20	0.0-2.0	29.4	7.8	2.4 ±0.1		0.9 ±0.8	1.5 ±1.0	27.3 ±2.2	10.5 ±2.3	0.22 ±0.15	0.50 ±0.16	0.81 ±0.17	17 ±7	0.60 ±0.03	0.65 ±0.13	0.21 ±0.11
M1	6/20	5.0	28.8	7.5	1.9 ±0.3		4.0 ±2.5	1.6 ±0.5	24.8 ±4.2	8.0 ±2.8	0.47 ±0.24	0.66 ±0.30	0.59 ±0.27	31 ±17	0.56 ±0.08	0.74 ±0.11	0.20 ±0.07
M1	7/18	0.0-2.5	30.0	7.4	1.4 ±0.6		2.9 ±1.5	5.7 ±0.0	27.9 ±3.8	0.3 ±0.5	0.26 ±0.06	0.69 ±0.10	0.67 ±0.28	25 ±7	0.19 ±0.04	0.65 ±0.11	0.06 ±0.09
M1	7/18	5.0	30.0	7.3	1.8		1.8	5.1	25.8	10.4	0.32	0.68	0.84	28	0.21	0.78	0.09
M1	10/09& 10	0.0-2.5	21.3	7.4	2.4 ±0.2		0.5 ±0.4	4.0 ±1.8	27.9 ±5.1	6.6 ±3.3	0.73 ±0.08	0.92 ±0.20	1.30 ±0.25	51 [illegible]	0.46 ±0.05	0.86 ±0.23	0.09 ±0.08
M1	10/09& 10	5.0	21.6	7.4	2.6 ±0.8		0.7 ±0.2	4.9 ±4.1	20.7 ±1.2	9.4 ±18.4	0.89 ±0.41	1.07 ±0.75	1.28 ±0.66	50 ±0	0.52 ±0.00		

± values represent 95% of conference intervals equivalent to ±1.96 times standard error of the mean value. The absence of a ± value means only one analysis was performed.

Table A2. (Continued)

Sta.	1978 Date	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg C	Dis Org. C	Undis Org. C
							µg-at/l								mg-at/l		
M1	12/01	0.5	17.8	7.4	1.6		4.4	4.4	30.3	8.1	1.23	1.49	0.45	53	0.51	0.70	0.00
M1	12/14& 15	0.0-2.0	11.2	7.4	2.4 ±0.5		4.3 ±1.9	9.2 ±1.8	26.6 ±1.8	1.2 ±1.4	1.39 ±0.29	1.65 ±0.24	0.72 ±0.31	70 ±11		1.05 ±0.41	0.09 ±0.05
M1	12/15	10.0	11.5	7.5	2.6 ±0.0		2.4 ±2.7	10.2 ±1.2	30.4 ±0.5	0.0 ±0.0	1.05 ±0.04	1.34 ±0.04	0.90 ±0.25	59 ±10		0.75	0.17
M2	2/14	0.0-1.0	8.1		3.9 ±0.1	1.25 ±0.02						1.36 ±0.38	0.08 ±0.16	71 ±31			
M2	3/15	0.0-1.5	17.1	8.6	3.4 ±1.0		16.5 ±3.2	9.9 ±10.3	12.4 ±24.3	2.0		1.65 ±0.19	0.92 ±0.41	112 ±7	0.63 ±0.10	2.03 ±0.09	0.90 ±0.40
M2	3/15	4.0	15.1	8.0	3.1		0.0	3.1	30.6	18.4		0.71	1.39	68	0.73	1.89	1.35
M2	4/25	0.0-3.5	23.1	8.1	5.2 ±0.2		1.4 ±0.3	0.9 ±1.4	20.4 ±9.3	11.6 ±8.4	0.24 ±0.19	0.38 ±0.19	1.03 ±0.42	36 ±6	0.92 ±0.07	0.85	0.66
M2	5/23	0.0-3.0	28.0	8.8	3.1 ±0.2	0.98 ±0.04	1.8 ±0.6	1.2 ±0.4	21.3 ±5.1	7.9 ±3.9	0.29 ±0.12	0.54 ±0.18	0.55 ±0.26	22 ±7		0.36 ±0.24	0.15 ±0.11
M2	5/23	4.0	26.6	7.8	4.2 ±0.4	1.22	3.2 ±1.0	2.2 ±4.3	21.6 ±2.9	9.4 ±6.6	0.03 ±0.00	0.50 ±0.61	0.24 ±0.47	33 ±5		0.43 ±0.66	0.22 ±0.05
M2	7/18	0.0-3.0	30.8	8.4	3.7 ±0.1		0.8 ±0.3	0.6 ±0.2	23.2 ±3.1	19.4 ±5.4	0.58 ±0.37	0.66 ±0.41	0.18 ±0.35	12 ±0	[illegible]	0.46 ±0.04	0.10 ±0.19

* ± values represent 95% of confidence intervals equivalent to ±1.96 times standard error of the mean value. The absence of a ± value means only one analysis was performed.

Table A2. (Continued)

Sta.	1978 Date	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg C	Dis Org. C	Undis Org. C
							μg-at/l								mg-at/l		
M2	7/18	4.0	30.0	8.2	3.9		4.4	2.1	29.1	8.6	1.00	0.96	0.06	41	0.64	0.57	0.04
M2	9/19	0.0-2.5	29.2	8.0	5.1 ±0.4		0.8 ±0.5	1.2 ±0.5	22.[illegible] ±4.4	5.9 ±4.0	0.47 ±0.14	0.6[illegible] ±0.19	0.6[illegible] ±0.20	32 ±8	1.22 ±0.20	1.35 ±0.45	0.08 ±0.06
M2	9/19	4.0	29.2	7.6	4.0 ±2.5		0.1 ±0.2	1.6 ±1.1	18.7 ±11.4	6.4	0.36 ±0.19	0.55 ±0.31	0.61	23 ±11	1.17	1.46 ±1.51	0.00 ±0.00
M2	10/10	0.0-1.5	23.0	8.3	5.4 ±0.7		11.2 ±1.7	1.4 ±0.8	16.2 ±2.2	8.1 ±9.8	0.89 ±0.03	1.03 ±0.00	1.15 ±1.05		0.7[illegible] ±0.20		
M2	10/10	4.0	23.1	8.4	6.2		21.1	0.0	10.4	25.4	0.90	1.03	4.58		0.55		
M2	10/30	0.0-2.5	22.8	8.3	5.5 ±1.2		0.1 ±0.2	1.0 ±1.0	26.1 ±1.7	3.6 ±2.2	0.96 ±0.20	1.12 ±0.16	0.80 ±0.48	66 ±15	0.61 ±0.02	1.08 ±0.44	0.02 ±0.04
M2	10/30	4.0	22.3	8.3	7.1 ±0.3		0.3 ±0.5	1.3 ±0.6	19.8 ±6.5	4.3	1.00 ±0.20	1.18 ±0.35	1.45	65 ±9	0.87 ±0.10	1.80 ±1.28	0.12 ±0.09
M2	11/10	0.5	21.2	7.7											0.79		
M3	4/25& 26	0.0-1.0	23.5	8.2	3.5 ±0.4		0.7 ±0.7	1.4 ±0.9	23.7 ±1.9	14.9 ±8.1	0.80 ±0.21	1.03 ±0.21	1.5[illegible] ±0.56	26 ±7	0.74 ±0.25	0.53 ±0.02	0.05 ±0.06
M3	4/25	9.0	23.4	7.7	17.8		19.8	0.0	28.6	0.0	1.58	2.00	0.48	42	1.61	0.19	0.07
M3	6/22	0.0-3.0	29.8	8.2	5.[illegible] ±0.8		1.2 ±0.5	2.[illegible] ±0.9	24.5 ±2.3	7.7 ±2.1	1.04 ±0.09	1.30 ±0.11	0.93 ±0.47	23 ±4	0.86 ±0.12	0.64 ±0.11	0.[illegible] ±0.06

* ± values represent 95% of confidence intervals equivalent to ±1.96 times standard error of the mean value. The absence of a ± value means only one analysis was performed.

Table A2. (Continued)

Sta.	1978 Date	Depth m.	Water Temp. °C	pH	Cond. mmhos/cm	Cl- g/l	NH_3 + NH_4^+ (µg-at/l)	NO_2^- + NO_3^- (µg-at/l)	Dis. Org. N (µg-at/l)	Undis. Org. N (µg-at/l)	PO_4^{3-} (µg-at/l)	Dis. P (µg-at/l)	Undis. P (µg-at/l)	Si (µg-at/l)	Inorg C (mg-at/l)	Dis Org. C (mg-at/l)	Undis Org. C (mg-at/l)
M3	6/22	10.0	29.5	7.6	13.7 ±1.6		29.6 ±5.2	2.8 ±4.1	12.0 ±5.0	2.9 ±1.8	3.67 ±0.64	4.08 ±1.28	0.79 ±0.43		1.41 ±0.05	0.49 ±0.03	0.16 ±0.05
M3	7/20	0.0-2.5	30.8	8.2	6.1 ±1.3		4.3 ±0.7	0.6 ±1.2	13.0 ±0.7	10.8 ±1.2	0.65 ±0.00	0.87 ±0.00	0.82 ±0.10	31 ±0	0.94 ±0.01	1.47 ±0.40	0.00 ±0.00
M3	7/20	9.0	30.5	8.0	12.1		14.5	3.1	16.8	2.0	1.39	1.65	0.71	47			
M3	9/21	0.0-3.0	29.1	8.1	5.1 ±0.3		1.2 ±0.5	8.3 ±2.9	23.2 ±4.6	5.9 ±1.9	3.37 ±0.25	3.79 ±0.21	0.69 ±0.29	52 ±2	1.57 ±0.14	0.66 ±0.03	0.13 ±0.08
M3	9/21	5.0	29.3	7.4	19.5		2.5	16.3	24.2	1.9	3.65	3.75	0.36	49	1.94	0.61	0.00
M3	9/21	9.0	29.7	7.5	4.7		0.0	15.9	21.6	0.0	2.74	3.16	0.00	51	1.96	0.53	0.21
M3	10/11	0.0-3.5	23.6	8.0	8.7 ±6.8		0.2 ±0.1	3.9 ±5.3	22.6 ±5.4	4.3 ±7.3	1.42 ±0.94	1.60 ±0.92	0.44 ±0.23	48 ±15	0.82 ±0.49	0.70	0.03
M3	10/11	8.0	24.2	7.7	12.8		3.4	6.6	22.1	8.0	1.90	2.23	0.36	50	1.10	0.51	0.05
M3	11/03	0.0-2.0	23.0	8.9	6.7 ±0.4		1.7 ±1.1	0.4 ±0.7	20.7 ±1.7	10.3 ±4.1	1.41 ±0.19	1.63 ±0.22	0.47 ±0.28	58 ±12	0.86 ±0.03	0.82 ±0.17	0.06 ±0.12
M3	11/03	4.0-5.0	22.6	8.7	7.8 ±1.0		3.7 ±2.3	2.7 ±2.6	20.4 ±1.4	5.2 ±6.5	1.50 ±0.09	1.61 ±0.17	0.10 ±0.19	58 ±19	1.15 ±0.27	0.77 ±0.25	0.06 ±0.09

* ± values represent 95% of conference intervals equivalent to ±1.96 times standard error of the mean value. The absence of a ± value means only one analysis was performed.

Table A2. (Continued)

Sta.	1978 Date	Depth m.	Water Temp. °C	pH	Cond. $\frac{\text{mmhos}}{\text{cm}}$	Cl- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg C	Dis Org. C	Undis Org. C
							ug-at/l								ug-at/l		
M3	11/03	10.0	22.4	8.2	21.0 ±0.4		8.8 ±0.7	4.0 ±3.3	27.6 ±18.9	4.0 ±7.7	1.78 ±0.07	1.92 ±0.10	0.53 ±0.47	44 ±6	1.61 ±0.06	0.63 ±0.15	0.05 ±0.10
M3	11/20	0.5	21.0	8.2	7.0 ±1.1		0.1 ±0.2	0.9 ±0.0	19.4 ±3.8	5.0 ±2.7	0.82 ±0.10	1.16 ±0.25	0.76 ±0.28	12 ±1	0.83 ±0.01		
M4	5/24	0.0-1.5	27.0	7.5	2.1 ±0.4	0.69 ±0.41	3.8 ±0.9	9.2 ±1.9	13.6 ±5.8	4.2 ±2.1	0.53 ±0.19	0.79 ±0.15	0.75 ±0.26	66 ±7		0.85 ±0.20	0.23 ±0.21
M4	5/24	8.0	26.7	7.5	2.1 ±0.6	0.58 ±0.29	4.6 ±1.2	7.1 ±2.7	19.1 ±11.8	3.1 ±1.0	0.26 ±0.14	0.53 ±0.22	1.25 ±0.50	71 ±23		0.52 ±0.65	0.67 ±0.74
M4	9/20	0.0-3.0	29.5	7.7	12.4 ±0.3		0.7 ±0.5	1.4 ±0.7	16.8 ±5.6	6.9 ±2.7	0.51 ±0.08	0.77 ±0.10	0.86 ±0.21	74 ±4	1.00 ±0.05	0.59 ±0.03	0.03 ±0.06
M4	9/20	10.0	29.5	7.7	13.4		0.9 ±0.1	1.6 ±1.6	20.1 ±7.4	5.0 ±7.6	0.55 ±0.37	0.71 ±0.06	1.25 ±0.79	77	1.05 ±0.07	0.57 ±0.05	0.01 ±0.01
M4	10/11	0.0-2.0	23.1	7.9	13.0 ±0.8		0.0 ±0.0	1.1 ±2.1	18.1 ±12.7	2.3 ±4.5	0.47 ±0.03	0.68 ±0.06	0.50 ±0.67	74 ±6	0.87 ±0.00	0.52	0.02
M4	10/11	10.0	22.9	7.9	14.5		0.6	1.2	12.8	0.0	0.39	0.45	1.00	65	0.94	0.64	0.19
M4	10/31	0.0-1.5	22.0	8.0	13.5 ±4.6		0.3 ±0.6	0.0 ±0.0	31.3	5.6	0.55 ±0.20	0.58 ±0.37	0.61	70 ±5	1.09 ±0.10		
M4	10/31	4.5	22.1	7.9	14.9		2.2	1.4	30.5	3.9	1.07	0.74	0.42	88	1.02	0.81	0.00

*± values represent 95% of conference intervals equivalent to ±1.96 times standard error of the mean value. The absence of a ± value means only one analysis was performed.

Table A2. (Continued)

Sta.	1978 Date	Depth m.	Water Temp. °C	pH	Cond. $\frac{\text{mmhos}}{\text{cm}}$	Cl- g/l	NH_3 + NH_4^+	NO_2^- + NO_3^-	Dis. Org. N	Undis. Org. N	PO_4^{3-}	Dis. P	Undis. P	Si	Inorg C	Dis Org. C	Undis Org. C
							ug-at/l								[illegible]-at/l		
M4	10/31	10.0	22.3	7.9	11.1		0.6	0.8	31.0	3.9	0.58	0.55	1.07	73	0.95	0.59	0.20
M4	11/21	0.0	22.0	7.8											1.13		
M4	11/21	5.0	22.0	7.8											1.05		

*± values represent 95% of confidence intervals equivalent to ±1.96 times standard error of the mean value. The absence of a ± value means only one analysis was performed.

APPENDIX 2

NUTRIENT AND GEOCHEMISTRY LAB MANUAL

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1979

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AMMONIA NITROGEN

Introduction

The method for ammonia determination is a modification by C. L. Ho and B. B. Barrett (1975) of the method developed by J. D. Strickland and T. R. Parsons (1972).

The basic chemistry is as follows:

A filtered (0.45μ membrane filter) water sample is made basic by the addition of magnesium oxide. This converts any ammonium ions into ammonia molecules. The sample is then steam distilled into dilute hydrochloric acid, thereby trapping the ammonia and eliminating any interference for color development from the sample matrix.

During the color development stage, the ammonia is oxidized to the nitrite radical in a basic sodium hypochlorite-potassium bromide solution, and after sufficient reaction time, the excess oxidant is poisoned by the addition of sodium arsenite.

Sulphanilamide in acidic solution is added and reacts with the nitrite radical and is subsequently diazotized with napthyl ethylene diamine diphyrochloride. This results in the formation of a highly colored azo dye, the absorbance of which can be determined colorimetrically.

TOTAL INORGANIC NITROGEN

The method for total inorganic nitrogen determination is a method developed by C. L. Ho and B. B. Barrett (1975).

The basic chemistry differs only at one stage from the chemistry of the ammonia determination: the reduction of the oxidized forms of nitrogen to ammonia. A filtered (0.45 μ membrane filter) water is made basic by the addition of magnesium oxide. This converts any ammonium ions into ammonia molecules. The nitrite and nitrate ions are reduced by Devarda's alloy to ammonia. All inorganic nitrogen is now in the form of ammonia and can be steam-distilled into dilute hydrochloric acid. Color development is the same as that listed under the ammonia determination.

Reagents

Light magnesium oxide (MgO)

Ignite heavy MgO in a muffle furnace at 800°C for 3 hours. Store promptly in airtight containers. Transfer a small amount to a small container for use during distillation; renew often.

Devarda's Alloy

This alloy of zinc, copper, and aluminum comes in granular form. Mechanically grind several small portions to 200 mesh and store in an airtight container. As with MgO, use a small container for use during distillation and renew often.

6N HCl

Add 1500 ml con HCl to 1500 ml distilled deionized water. Distill and collect the fraction that boils at 110°C. Store in a glass bottle.

0.4N HCl

Dilute 66.6 mls of 6N HCl to 1000 ml with distilled deionized water.

0.1N HCl

Dilute 16.6 ml of 6N HCl to 1000 ml with distilled deionized water.

NaOH-KBr solution

Dissolve 168 grams of NaOH in 500 ml distilled water. Add 8 grams KBr and make up to final volume of 1000 ml. Store in a polyethylene bottle.

Chlorox-NaOH/KBr solution

Prepare this solution and allow to sit for 15 minutes before use. It is good for up to 3 hours after preparation. Add 5 ml of fresh Chlorox (or any comparable chlorine bleach containing 5% or 1.5 N sodium hypochlorite) to 100 ml of NaOH/KBr solution.

Sodium Arsenite solution

Add 20 grams arsenic trioxide (As_2O_3) to 100 ml of distilled water and stir. Dissolve 30 grams of NaOH in 300 ml distilled water. Add the arsenic trioxide slurry to the sodium hydroxide solution. Dilute to a final volume of 500 ml.

Sulphanilamide solution

Stir 10 grams sulphanilamide into 200 ml distilled water. Add slowly 300 ml of con HCl. When dissolved completely, dilute to 1 liter.

Napthyl ethylene diamine dihydrochloride solution

Dissolve 0.5 grams of (NEDD) in 500 ml water. Store in amber glass bottle. Renew after 3 - 4 weeks, as this solution deteriorates fairly quickly.

After analysis, decant all colored waste solutions into a waste bottle containing activated charcoal.

Standards

Ammonia stock solution

Dry good quality ammonium sulfate ($(NH_4)_2SO_4$) at 100°C for 1 hour. Weigh out 4.7187 grams and dilute to 1 liter for 1 mg (NH_3)-N/ml.

Total Inorganic Nitrogen stock solution

Dry good quality potassium nitrate (KNO_3) at 100°C for 1 hour. Weigh out 7.2219 grams and dilute to 1 liter for 1 mg (NO_3)-N/ml.

Glassware Cleaning

To reduce contamination by atmospheric ammonia, suspend the use of aqueous ammonia in lab.

Immediately prior to analysis, clean all glassware by rinsing with 0.4N HCl followed by 3-4 rinses of distilled deionized water.

Keep the distilling flasks full of distilled deionized water and stoppered until needed.

Add 2 ml 0.1N HCl to each 50 ml volumetric flask and leave stoppered.

Method (NH_3) and (TIN)

1. Fill steam generator to the full line with distilled water. Turn on distillating unit and cold water circulator at least two hours before use. Start distillations when generator is producing distillate at a rate of 6.5 ml/min.

2. Defrost samples under running, cool water.

3. When completely defrosted, pipette in duplicate 25 ml aliquots of blanks, samples, and standards into pre-cleaned, labeled distillation flasks. Label 50 ml volumetric flasks in which distillates are to be collected.

4. Prepare ammonia and TIN standards as follows:

Dilute 1 ml of stock solution to 1000 ml. The concentration will be 1μg ( )-N/ml. Use 2-5 ml of this solution as the standard.

5. Reduce nitrogen contamination from the atmosphere (or as carry over between distillation of samples [or standards]) by steam distilling an aliquct of 0.4N HCl for 3 minutes, followed by the steam distillation of an empty clean flask for 1 minute. Use this precautionary procedure prior to distillation of blank and between each subsequent distillation of sample or standard.

6. For ammonia determination: To a 25 ml distilled water blank add 0.03 grams (approx.) of light MgO. Begin steam distilling and collect distillate in the pre-labeled volumetric flask for 3 minutes timed from

the appearance of the first drop through the condenser. Remove the distillation flask promptly. Stopper volumetric flask and set aside.

Repeat step 5 above.

7. Steam distill a 25 ml aliquot of each sample as described above after the blank. Finally, steam distill the standards (diluted to 25 ml).

For total inorganic nitrogen--Repeat precautionary distillation of 0.4N HCl followed by empty distillation flask as in step 5.

6. To a 25 ml distilled water blank, add approximately 0.05 g Devarda Alloy and 0.4 g light MgO. Steam distill and collect distillate for 4 minutes.

7. Steam distill a 25 ml aliquot of each sample as described for blank. Finally, steam distill the nitrate standards (diluted to 25 ml).

Color Development

1. Prepare NaOH/KBr/Chlorox oxidizing solution and leave to stand for at least 15 minutes.

2. Add 5 ml of oxidizing solution to each distillate in 50 ml volumetric flasks. Swirl to mix. Time 30 minutes from the first addition.

3. After the 30 minute period, add 1 ml sodium arse-nite solution to each flask. Time 5 minutes from the first addition.

4. Add 6.5 ml sulphanilamide solution and swirl. Follow with 1 ml NEDD solution, swirl, and make up to

50 ml volume with distilled water. Treat each distil-late in a similar fashion. Time 15 minutes from treatment of first distillate.

5. After 15 minutes, check each 50 ml meniscus.

6. Read absorbances of blanks, samples, and standards (maintaining the order in which they were treated for color development) at 543 nm using a reference cell of distilled water.

Calculations

Using the following equation derived from Beer's, Lambert Law, calculate the unknown sample concentrations.

$$\frac{Abs_{(std)} - Abs_{(blank)}}{conc_{(std)}} = \frac{Abs_{(sample)} - Abs_{(blank)}}{conc_{(sample)}}$$

therefore

$$Conc_{(sample)} = \frac{Abs_{(sample)} - Abs_{(blank)}}{Abs_{(std)} - Abs_{(blank)}} Conc_{(std)}$$

$$Conc_{(sample)} = Abs_{(sample)} - Abs_{(blank)} \times F$$

The values computed in μg are for the initial sample volume; 25 ml. Results may be reported as μg/ml or μg/l.

References

Strickland, J. D. H., and T. R. Parsons (1972), A Practical Handbook of Seawater Anaylsis, Fisheries Research Board of Canada, Ottawa.

Ho, C. L., and B. B. Barrett (1975), Distribution of Nutrients in Louisiana's Coastal Waters, La. Wildlife and Fisheries Bulletin 17.

KJELDAHL NITROGEN

Introduction

Kjeldahl nitrogen is that fraction of nitrogen that is released to the ammonia form by a severe digestion. If performed on a filtered water sample, the results will be the sum of two fractions: the ammonia fraction plus the dissolved reduced organic fraction. Neither oxidized inorganic nor oxidized organic nitrogen responds to this digestion.

If an unfiltered water sample is digested, the results will be the sum of three fractions: ammonia fraction, dissolved reduced organic fraction, and the reduced particulate fraction.

The acid digestion consists of a primary dewatering step followed by a severe acid digestion with K_2SO_4/-$CuSO_4$/Se at 370°C for one hour.

After digestion, the samples are transferred to distillation flasks, and NaOH is added to neutralize the acid and release the ammonia formed. The basic digest is then steam distilled into dilute acid. Color development may be accomplished by the oxidation method (see ammonia) or through Nesslerization in which an alkaline mercurous solution forms a stable colored complex with ammonia. The absorbance of this complex can then be determined colorametrically.

Reagents

$36N\ H_2SO_4$

Concentrated reagent.

Kjeldahl catalyst

Grind by hand a large quantity of potassium sulfate (K_2SO_4) until it becomes a fine powder. Separately grind a large quantity of copper sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) until it is a fine powder. When needed, mix 100 grams K_2SO_4 with 10 g $CuSO_4 \cdot 5H_2O$ and add 1 gram powdered selenium. Cap container and shake until a uniform gray color is observed.

10N NaOH

Dissolve 400 grams NaOH in 500 ml distilled water and make up to 1 liter of solution.

Nessler reagent

Dissolve 35 grams potassium iodide in 100 ml distilled water; add 4% mercuric chloride solution (about 400-500 ml) with stirring until a slight red precipitate remains. Add a solution of 120 grams NaOH in 250 ml water. Add a little more $HgCl_2$ solution until there is a permanent turbidity. Allow the mixture to stand for 24 hours and decant or filter. Dilute to 1 liter. Store in a dark bottle.

Standards

Ammonia stock solution

Dry good quality ammonium sulfate ($(NH_4)_2SO_4$) at 100°C for 1 hour. Weigh out 4.7187 grams and dilute to 1 liter for 1 mg (NH_3)-N/ml.

Glassware cleaning

To reduce contamination by atmospheric ammonia, suspend the use of aqueous ammonia in lab.

Immediately prior to analysis, clean all glassware by rinsing with 0.4N HCl followed by 3-4 rinses of distilled deionized water.

Keep the distilling flasks full of distilled water and stoppered until needed.

Add 2 ml 0.1N HCl to each 50 ml volumetric flask and leave stoppered.

Method: Kjeldahl Nitrogen

1. Pipette 25 ml of sample into Kjeldahl test tubes. Pipette 10 ml or suitable amount 1 μg(NH_3) - N/ml into test tube. Use 25 ml distilled water as blank.
2. Add 1 gram Kjeldahl catalyst to each tube.
3. Add 3 ml $H_2SO_{4(con)}$ to each tube.
4. Put tubes on digestion block and set low temperature on 150 and low temperature time on 1.5 hours.
5. Set high temperature on 370°C and total time on 4 hours.
6. When samples have been digested, add a small amount of distilled water to each tube and stopper if to be left overnight.
7. Start up steam generator and cold water circulator at least two hours before distilling.
8. Reduce nitrogen contamination from the atmospheric (or as carryover between distilllation of samples or standards) by steam distilling an aliquot of

0.4N HCl for 3 minutes, followed by the steam distillation of an empty clean flask for 1 minute. Use this precautionary procudure prior to distillation of blank and between each subsequent distillation of sample of standard.

9. Transfer with 25 ml distilled deionized water the Kjeldahl blank to a distillation flask.

10. Remove the clip on the steam release vent.

11. Add 13 ml 10N NaOH to the funnel above the steam output tube.

12. Place the digestion flask on the unit and admit the NaOH to the distilling flask.

13. When the NaOH has been added, close the stopcock and replace the clip on the steam release vent.

14. Begin steam distilling and collect distillate in the pre-labeled volumetric flask for 3.5 minutes timed from the appearance of the first drop through the condenser. Remove the distillation flask promptly. Stopper volumetric flask and set aside.

15. Repeat step 8 above.

16. Steam distill each sample in the manner described above. Finally, steam distill the standards.

17. Color develop according to oxidation method (see Ammonia) or Nesslerization.

Nesslerization

1. Add distilled water to volumetric flask to within 5 ml of full volume line.

2. Add 2 ml Nestler's reagent.

3. Dilute to 50 ml.

4. Wait 15 minutes.

5. Read sample absorbance at 402 nm against a reference cell of water.

6. After analysis, collect all Nesslerized liquids and put them in the mercury waste bottle.

Calculations

Using the following equation derived from Beer's, Lambert Law, calculate the unknown sample concentrations.

$$\frac{Abs_{(std)} - Abs_{(blank)}}{conc_{(std)}} = \frac{Abs_{(sample)} - Abs_{(blank)}}{conc_{(sample)}}$$

therefore

$$Conc_{(sample)} = \frac{Abs_{(sample)} - Abs_{(blank)}}{Abs_{(std)} - Abs_{(blank)}} Conc_{(std)}$$

$$Conc_{(sample)} = Abs_{(sample)} - Abs_{(blank)} \times F$$

The values computed in µg are for the initial sample volume: __ ml. Results may be reported as µg/ml or µg/l.

PHOSPHORUS

Introduction

Phosphorus fractions: The P fractions analyzed include dissolved inorganic phosphate (PO_4^{-3}) and dissolved and total phosphorus. The method for dissolved inorganic phosphate used in this study is that described by Ho and Barrett (1975), which was modified from Strickland and Parsons (1972). Dissolved and total phosphorus were measured by the persulfate

digestion method in Standard Methods (Am. Public Health Assoc. 1976). A minor modification made on these methods was to store the separatory funnels in 1% H_2SO_4 after acid cleaning, as recommended by Strickland and Parsons (1972).

Inorganic Phosphate

An acidified filtered water sample is treated with a ammonium molybdate solution which converts the PO_4^{-3} fraction to a phosphomolybdate complex that is extracted with ethylacetate. This complex is reduced with ascorbic acid in the presence of antimonyl potassium tartrate to produce a highly-colored antimonylphosphomolybdous complex which is measured colorimetrically.

Dissolved and Total Phosphorus

An acidified filtered or unfiltered (for dissolved or total measurement) water sample is digested in a potassium persulfate solution for 1/2 hour at 90°C to release the oxidizable organic phosphorus as inorganic phosphate. The PO_4^{3-} is then determined as described above for PO_4^{3-}.

Reagents

Ammonium molybdate solution

Dissolve 15 grams of analytical reagent quality ammonium paramolybdate $(NH_4)_6MO_7O_{24} \cdot 4H_2O$ in 500 ml distilled water. Store in small aliquots in plastic bottles in freezer.

Sulphuric acid solution

Add 140 ml concentrated analytical reagent quality sulphuric acid to 900 ml distilled water. Allow the solution to cool before use.

Ascorbic acid solution

Dissolve 27 grams good quality ascorbic acid in 500 ml of distilled water. Store in small aliquots in plastic bottle in freezer. Unstable; deteriorates rapidly at room temperature.

Potassium antimonyl-tartrate solution

Dissolve 0.34 grams of good quality potassium antimonyl tartrate in 250 ml distilled water. Can be stored in glass or plastic. Store in small aliquote in freezer.

Ethyl acetate

Reagent.

Ethanol 95%

Reagent.

50% Ethanol/water

Add 100 ml ethanol to 100 ml water. Let sit for 10 minutes before use.

Standards — Dissolve 4.3937 grams good quality potassium dihydrogen phosphate KH_2PO_4 in 1 liter of distilled water. This stock solution is 1 mg (PO_4) - P/ml.

Glassware Cleaning (Special) — Rinse all glassware with 1% H_2SO_4. Store separatory funnels in 1% H_2SO_4 between uses.

Method Phosphate

1. Measure 100 ml ± 1 ml distilled water for blank, samples, and standards into clean labeled 250 ml separatory funnels. Group separatory funnels into sets of 5. Follow the procedure for each set.

2. Add 50 ml 22.5% (w/w) H_2SO_4, start timer, and shake vigorously. After 1 minute has elapsed, add 5 ml acid to the second separatory funnel. Continue until acid has been added to each separatory funnel in the set.

3. When 5 minutes has elapsed, add 4 ml ammonium molybdate solution to the first separatory funnel, start timer, and shake vigorously. After 1 minute has elapsed, add 4 ml of solution to the second separatory funnel. Continue in this manner for the set.

4. When 5 minutes has elapsed, add 18 ml ethyl acetate to the first separatory funnel and shake vigorously for 45 seconds. Continue in this manner for the set.

5. Allow layers to separate.

If there is more than one set, start with step 2 again; if not, go on to step 6.

6. When layers have separated, draw off the water layer through the stopcock.

7. Add 4 ml ascorbic acid solution, carefully running it down the inside of the separatory funnel.

running it down the inside of the separatory funnel.

9. Shake vigorously.

10. Allow layers to separate.

11. Draw off the colorless water layer through the stopcock.

12. Pour out the blue ethyl acetate layer through the top of the separatory funnel into a 10 ml graduated cylinder.

13. Add enough 95% ethanol to obtain a volume of 10 ml.

14. Pour contents of graduated cylinder into 50 ml erlenmeyer flasks; cap; wait 15 minutes.

15. Read absorbance at 690 nm against a reference cell of 50% ethanol/water mixture.

Calculations

Using the following equation derived from Beer's, Lambert Law, calculate the unknown sample concentrations.

$$\frac{Abs_{(std)} - Abs_{(blank)}}{conc_{(std)}} = \frac{Abs_{(sample)} - Abs_{(blank)}}{conc_{(sample)}}$$

therefore

$$Conc_{(sample)} = \frac{Abs_{(sample)} - Abs_{(blank)}}{Abs_{(std)} - Abs_{(blank)}} Conc_{(std)}$$

$$Conc_{(sample)} = Abs_{(sample)} - Abs_{(blank)} \times F$$

The values computed in µg are for the initial sample volume __ ml. Results may be reported as µg/ml or µg/l.

$$\frac{Abs_{(std)} - Abs_{(blank)}}{conc_{(std)}} = \frac{Abs_{(sample)} - Abs_{(blank)}}{conc_{(sample)}}$$

therefore

$$Conc_{(sample)} = \frac{Abs_{(sample)} - Abs_{(blank)}}{Abs_{(std)} - Abs_{(blank)}} Conc_{(std)}$$

$$Conc_{(sample)} = Abs_{(sample)} - Abs_{(blank)} \times F$$

The values computed in μg are for the initial sample volume: __ ml. Results may be reported as μg/ml or μg/l.

DISSOLVED SILICA

Introduction

The procedure of Strickland and Parsons (1965) is used to determine dissolved silica. There is a significant adsorption of silica on the walls of the polyethylene storage bottles that have been frozen. Upon defrosting, aqueous silica concentrations increase by a factor of 2 or 3 between 1 and 5 days after defrosting. Additional amounts of time have no significant effect.

A filtered sample that had been defrosted for a minimum of 5 days is mixed with an acidic ammonium molybdate solution to produce a silicomolybdate complex. Oxalic acid is added to destroy any phosphomolybdate complex present. The silicomolybdate complex is then reduced with a metol sulfite solution to form an intensely colored silicomolybdous complex, which is measured colorimetrically.

Method Total Dissolved Phosphorus, Total Phosphorus	1. Measure 50 ml distilled water, samples and standards into clean labeled 125 ml erlenmeyer flasks. 2. Add 1 ml of 75% (w/w) H_2SO_4 to each erlenmeyer flask. 3. Add 0.2 grams potassium persulfate to each flask. 4. Set flasks on a cold hot plate and increase the temperature to about 90°C for one hour. 5. Remove erlenmeyer flasks from heat and transfer contents to labeled separatory funnels. Rinse with enough water to bring the volume up to 100 ml. 6. Add 2 ml 22.5% H_2SO_4 and shake. 7. Start at step 3, method for orthophosphate.
	<u>Total Phosphorus</u>
Reagents	<u>75% H_2SO_4</u> Add 765.3 ml concentrated sulfuric acid to 200 ml water. When cool, dilute up to 1 liter. <u>Potassium persulfate</u> Reagent. See ortho-phosphate for additional reagents.
Calculations	Using the following equation derived from Beer's, Lambert Law, calculate the unknown sample concentrations.

Reagents

<u>Ammonium molybdate solution</u>

Add 4 grams ammonium paramolybdate to 300 ml distilled water. Add 12 ml concentrated hydrochloric acid in 500 ml water. Mix the two solutions for a final volume of 800 ml. Store in plastic.

<u>Metol sulfite solution</u>

Add 6 grams anhydrous sodium sulfite to 500 ml water. Add 10 grams metol sulfite (p-methylaminophenol-sulfate). Stir until there are no more crystals. Store in glass. Stable for 1 month.

<u>Oxalic acid solution</u>

Add an excess 50 grams oxalic acid dihydrate to 500 ml water. Keep crystals on bottom to insure that the solution remains saturated.

<u>18N sulfuric acid</u>

Dissolve 500 ml concentrated sulfuric acid into 500 ml dionized water.

<u>Reducing solution</u>

Add 100 ml metol sulfite solution, 60 ml oxalic acid solution, and 60 ml sulfuric acid solution to an erlenmeyer flask; mix; dilute to 300 ml. Use within 1.5 hours. Neutralize and discard after use.

Standards

Add 4.7300 g sodium metasilicate to 1 liter of solution for a concentration of 1 mg SiO_2/ml.

Glassware Cleaning

No special requirements.

Method Dissolved Silica

1. Add 10 ml ammonium molybdate into labeled 50 ml volumetric flasks. Group into sets of 8.

2. Pipette 10 ml deionized water for blank and 10 ml sample into the ammonium molybdate and mix.

3. Let sit at least 10 minutes but not more than 30 minutes.

4. Add 15 ml reducing solution, mix, and dilute up to 50 ml line.

5. Let sit for 2-3 hours.

6. Read absorbance at 763 nm against distilled water.

Calculations

Using the following equation derived from Beer's, Lambert Law, calculate the unknown sample concentrations.

$$\frac{Abs_{(std)} - Abs_{(blank)}}{conc_{(std)}} = \frac{Abs_{(sample)} - Abs_{(blank)}}{conc_{(sample)}}$$

therefore

$$Conc_{(sample)} = \frac{Abs_{(sample)} - Abs_{(blank)}}{Abs_{(std)} - Abs_{(blank)}} Conc_{(std)}$$

$$Conc_{(sample)} = Abs_{(sample)} - Abs_{(blank)} \times F$$

The values computed in µg are for the initial sample volume __ ml. Results may be reported as µg/ml or µg/l.

CARBON

Introduction

Carbon fractions: The analyzed C fractions include total inorganic carbon (TIC), total organic carbon (TOC), and dissolved organic carbon (DOC). These fractions are measured on a multicomponent analyzer system, "The Total Carbon System" manufactured by Oceanography International Corporation (OIC). The components consist of purging module, a Horiba Model PIR-2000 non-dispersive infrared analyzer, and an integrator. The methods used in this study are those given by OIC (1978) in the instruction and procedure manual of the model 0524B.

Total Inorganic Carbon

A filtered water sample is injected directly into a strong mineral acid solution. The solution is purged with nitrogen, and the released CO_2 is measured on an infrared analyzer. The method used is from OIC Instruction manual.

Total Organic Carbon and Dissolved Organic Carbon

Potassium persulfate is added to a precombusted ampule and followed by the addition of an aliquot of an unfiltered or filtered (TOC or DOC measurement) water sample, up to 5 ml of distilled-deionized water, and 0.25 ml of phosphoric acid. The solution is purged of inorganic carbon with oxygen, and the ampule is sealed. Oxidation of organic carbon to CO_2 takes place by heating the ampule in a pressure vessel for 24 hours at 175°C, 2 hours at 121°C and 16

psi. The ampule is then broken; the CO_2, released by nitrogen purging; and subsequently, measured on the infrared analyzer. The method used is from OIC Instruction manual.

CHLOROSITY

See method from Strickland and Parsons (1972).

CONDUCTIVITY

Measured on a Lab-line Lectro MHO meter model MC-1 Mark IV.

Coast Guard headquarters near the New Orleans Southern Yacht Club

Chapter 7

STRUCTURE AND FUNCTION OF THE PHYTOPLANKTON COMMUNITY IN LAKE PONTCHARTRAIN, LOUISIANA

by

David D. Dow
and
R. Eugene Turner

ABSTRACT

Lakewide surveys of Lake Pontchartrain were conducted to examine the spatial and temporal variation in standing crop biomass of phytoplankton and photosynthetic production from February 1978 to April 1979. Monthly average chlorophyll a concentrations for stations sampled were highest in March and April (15.4 and 13.7 μg/l) and lowest in December (5.2 μg/l). The sampling stations off the Elmwood (S6) and Bonnabel Canals (S7) exhibited the highest yearly average standing crop levels (17.4-19.2 μg/l), which are probably a reflection of the enriched nutrient regimes in this region of the lake. The temporal variation in chlorophyll a levels is quite large. The station at the mouth of the Tchefuncte River (S1) had a maximum chlorophyll a concentration at the surface of 228.4 μg/l in May and a minimum concentration of 1.1 μg/l in December. The maximum standing crop was associated with a surface bloom of the blue-green alga, *Anabaena*, and this phenomenon was associated with freshwater emanating from the Tchefuncte River and from Pass Manchac. Spatial variation in standing crop biomass in April ranged from 4.5 μg/l at the Chef Menteur Pass (S13) to 59.5 μg/l at the Bonnabel Canal. Chlorophyll a

is the dominant photosynthetic pigment. For example, at MS3 (Inner Harbor Navigation Canal [IHNC]) the amount of pigment (Mg/m^2) averages 57.8 for chlorophyll _a_, 2.1 for chlorophyll _b_, and 17.9 for chlorophyll _c_.

Photosynthetic production was measured in a deckboard incubator that had a maximum light intensity of 295 microeinsteins$\cdot m^{-2} \cdot sec^{-1}$. The largest lakewide (average potential) productivity was in April 1979 (46.3 $\mu g\ C \cdot l^{-1} \cdot h^{-1}$) and the lowest, in October (18.6 $\mu g \cdot l^{-1} \cdot h^{-1}$). In December, the eastern half of Lake Pontchartrain was characterized by high assimilation ratios (carbon fixed per unit chlorophyll), and the result was a small standing crop biomass (5.2 μg/l) that supported a carbon fixation rate of 39.8 $\mu g\ C \cdot l^{-1} \cdot h^{-1}$. The master station at IHNC (MS3) had the highest potential production with a carbon fixation rate of 45.2 $\mu g\ C \cdot l^{-1} \cdot h^{-1}$; the lowest occurred at Pass Manchac (MS1), (18.5 $\mu g\ C \cdot l^{-1} \cdot h^{-1}$). A lakewide survey in October exhibited a fairly high degree of spatial variability in potential production with a minimum value of 1.5 $\mu g\ C \cdot l^{-1} \cdot h^{-1}$ off of South Point (S11) and a maximum value of 40.5 $\mu g\ C \cdot l^{-1} \cdot h^{-1}$ at our open lake reference station adjacent to the middle of the Causeway (MS2). Dredging operations in the vicinity of MS2 may account for the increased level of photosynthetic production. Short-term temporal variability in potential photosynthesis is illustrated at MS3 (IHNC) where the rate increased from 11.3 to 106.2 $\mu g\ C \cdot l^{-1} \cdot h^{-1}$ from November to December. _In situ_ incubations at the four master stations gave the following average photosynthetic rates for the euphotic zone ($\mu g\ C \cdot m^{-2} \cdot h^{-1}$): MS1 (Pass Manchac): 32.3; MS2 (open lake adjacent to middle of Causeway): 49.4; MS3 (IHNC): 84.6; and MS4 (The Rigolets): 44.5. These values include particulate and dissolved production. Dissolved

production is approximately 18% of total production at MS3 and MS4 and 35% of total production at MS1 and MS2.

The structure and activity of the phytoplankton do not seem to be coupled either temporally or spatially between the western two-thirds of Lake Pontchartrain and the eastern third of the lake. Results from our field studies and laboratory bioassays suggest that the plankton in Lake Pontchartrain are light limited in the winter, nitrogen limited in the summer and fall, and possibly phosphorus limited in the late spring. These limiting factors are probably controlled by hydrological and meteorological events. Passage of cold fronts in the winter reduces transparency in the water because of the suspension of inorganic material in the water column. The light-photosynthesis curves are of the shade-adapted type at this time. In the summer and fall, the prevailing winds from the south and southeast push higher conductivity, low inorganic nitrogen water from offshore into Lake Pontchartrain. Higher evapotranspiration in the watershed during this time decreases the runoff into Lake Pontchartrain and decreases the flux of nitrogen into the lake. Early spring is a time of active phytoplankton growth that may reduce the levels of availa. e phosphorus in the water column. The outfall canals draining the Metropolitan New Orleans area may be important local sources of nutrient enrichment to the Lake Pontchartrain system, but their contribution to the lakewide nutrient budget remains unclear. The phytoplankton respond to this varying regime of limiting factors by acting as a pulsed system. The result is rapid growth during favorable periods and lower activity during the intervening periods.

INTRODUCTION

In the fall of 1977, a multidisciplinary survey was initiated in Lake Pontchartrain to examine the interaction between the bottom community, fish and shellfish, wetlands, and the pelagic zone. The quantitative measurement of planktonic biomass and primary production had not been attempted in the previous descriptive surveys of the Lake Pontchartrain pelagic zone (Stern et al. 1968, Stern and Stern 1969, Hawes and Perry 1978, U.S. Geological Survey [USGS] 1977). Because the plankton community is an important element of both the pelagic and benthic food webs, it is important to understand how its distribution and activity is coupled with the physical and chemical forcing factors in the pelagic zone. Our study of the plankton community was facilitated through the integration of the other sampling program for hydrography and nutrient chemistry. The descriptive aspects of phytoplankton and zooplankton distribution will be covered in Chapter 8.

The sampling program started February 1978 and was completed April 1979. The field surveys of the water column in Lake Pontchartrain provided information on the temporal and spatial variation in planktonic biomass and productivity, nutrient chemistry, and physical parameters. The surveys were augmented by other "experimental" cruises and laboratory bioassays to provide an explanation of the observed temporal and spatial variability. Meteorological data gathered by the National Oceanic and Atmospheric Administration (NOAA) were also incorporated in this synthesis. Our findings were related to other comparable coastal estuaries.

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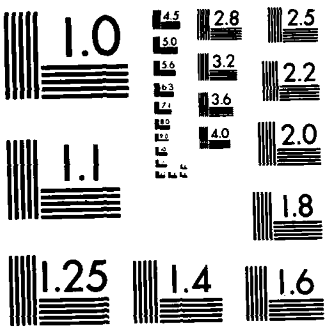

MICROCOPY RESOLUTION TEST CHART
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Descriptive information on the physical, chemical, and biological parameters in Lake Pontchartrain was obtained from survey cruises of two types: one-day survey cruises designed primarily for constructing maps of the distribution of temperature, conductivity, and *in vivo* fluorescence (which reflects the distribution of chlorophyll *a* in the surface water); and two-day survey cruises of 18 stations throughout the lake (Fig. 1) that gathered information on the variation of planktonic biomass and photosynthetic activity with depth as well as the accompanying changes in a variety of chemical and physical parameters. Considerable detail on the temporal and spatial variations in selected chemical, physical, and biological parameters was gathered at four of these stations: MS1 (Pass Manchac), MS2 (Open Lake Reference station in the middle of the lake just east of the Lake Pontchartrain Causeway), MS3 (IHNC), and MS4 (The Rigolets). These locations were chosen to represent the three major passes that presumably act as forcing functions for the lake and an open lake reference station. These four "master" stations were sampled more often than the other 14 survey stations, so they represent the best hope for elucidating seasonal trends in biomass and productivity and for applying multiple regression techniques to relate measured levels of photosynthetic production with related biological, chemical, physical, and meteorological parameters.

I. Chlorophyll

The chlorophyll pigments *a*, *b*, and *c* were analyzed spectrophotometrically using the equations of Strickland and Parsons (1965). Sample water was filtered through 0.45 micron HA Millipore filters at low

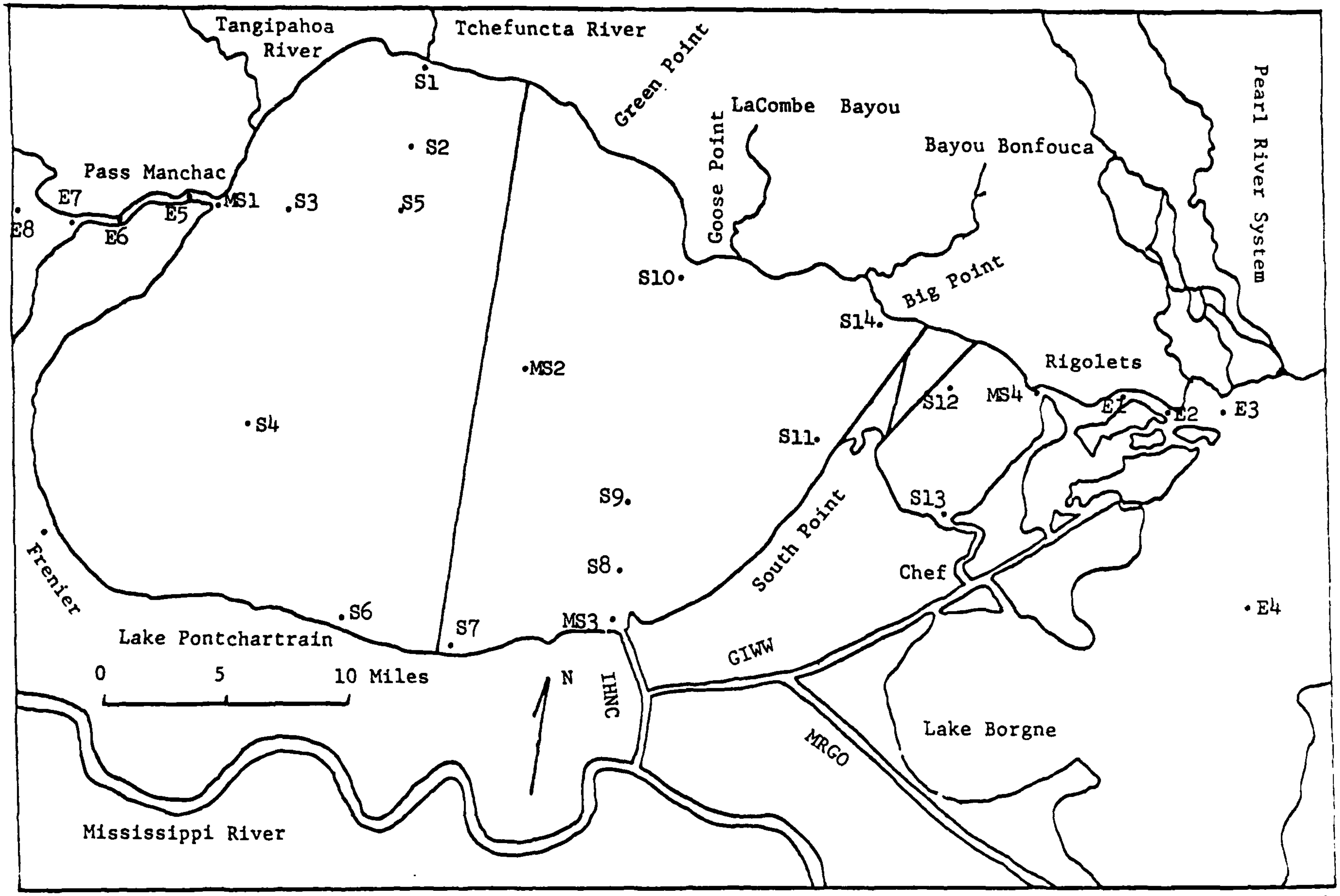

Figure 1A. The location of the master stations (MS) and experimental stations (E) for the plankton survey conducted in Lake Pontchartrain, LA, in this study.

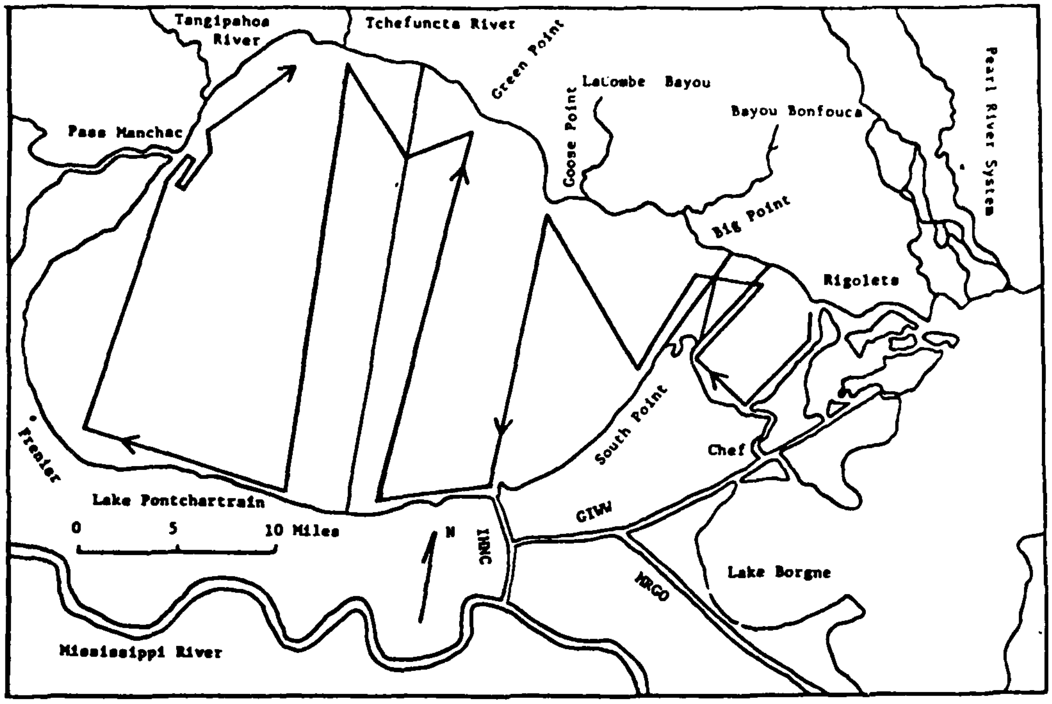

Figure 1B. The cruise track used for the determination of the *in vivo* fluorescence.

vacuum pressure (10-16 psi). The filters were placed in brown bottles containing 90% acetone and put in a freezer for 24 hours to extract the chlorophyll pigments. Samples were acidified with two drops of 50% HCL to estimate phaeopigment concentration (chlorophyll degradation products).

II. Phytoplankton Production

Photosynthesis was measured using the carbon-14 method either *in situ* or in a deckboard incubator system. The deckboard incubator employed incandescent lights with a tungsten filament that produced a maximum light intensity of 295 microeinsteins$\cdot m^{-2} \cdot sec^{-1}$. Samples were maintained at *in situ* temperatures by pumping surface water through the incubator. Samples were incubated in 50 ml glass bottles for 3 to 4 hours at 100, 73, 35, 14, 6, and 1% light intensity. The glass bottles (containing 2.5 microcuries of carbon-14) and the prefiltered water sample (all organisms larger than 145 m were removed) were only illuminated from above. The short incubation periods were thought to preclude the possibility of serious nutrient limitation during the period of the incubations. All water samples were collected in plastic water samplers that were periodically cleansed with 10% HCL and 95% ethanol.

We also measured phytoplankton production *in situ* at the four "master" stations. Sample bottles filled with water from three different depths (surface, 20%, and 1% of surface light) were suspended from a float back at the same depths in the water column. On a bright summer day, the irradiance at the surface ranges from 1000-2000 microeinsteins$\cdot m^{-2} \cdot sec^{-1}$ and generally decreases exponentially with depth. We carried out the incubations between 1000 and 1600 hr to make the results from different locations comparable with each other.

Following incubation the glass bottle, contents from the deck incubator or *in situ* incubation were filtered through 0.45 micron HA Millipore filters at low vacuum pressure (10-15 psi). Part of the filtrate was removed, acidified with phosphoric acid to pH 2.5-3.0, and bubbled with nitrogen gas for 20 minutes to remove the labelled inorganic carbon. One milliliter of this latter solution was then placed in a scintillation vial with 3A70B fluor (Research Products International) and counted in a Beckman Liquid Scintillation Counter. The Millipore filter was rinsed with previously filtered lake water to remove any inorganic carbon-14 adsorbed to the filter and then was placed in a scintillation vial for counting in the laboratory. All counts were corrected for quenching using an external standards ratio procedure and for the counting efficiency of the scintillation counter used. The counts were converted to mg $C \cdot m^{-3} \cdot hr^{-1}$ fixed by incorporating measurements of the concentration of inorganic carbon in the water at the start of the incubation. The activity in the filtrate measures dissolved production and that on the filter measures particulate production.

III. Fluorometry

Maps of *in vivo* fluorescence in Lake Pontchartrain were constructed to examine the broad distribution of chlorophyll *a*. An underway sampling system brought surface water to a debubbler, into a Turner Designs fluorometer fitted with a flow-through door, and then onto a temperature-conductivity probe. The fluorometer signal was continuously recorded on a strip chart recorder as the vessel cruised a prescribed cruise tract. The strip chart record was digitized at 0.5 mile intervals and the resulting values were contoured by hand. Calibration of the flurometer was

necessary, so water grab samples were collected periodically from the flow-through system for chlorophyll *a* and suspended sediment level determinations. For suspended sediments, a known volume of lake water was filtered through a tared, air dried 0.45 micron HA Millipore filter. A control filter below was used to correct for problems such as the failure to evacuate all of the water or the adsorption of salts on the filter. The filters were washed three times with deionized, distilled water to remove salts, removed from the filter apparatus, air dried over drierite for 4 to 7 days, and then reweighed. The difference in weight represents the weight of the suspended sediments. Linear regressions were then run comparing the *in vivo* fluorescence levels, chlorophyll *a* concentrations, and suspended sediment weights.

IV. Results

It is useful to evaluate first the distribution of Secchi disc depth, since it influences the depth of effective light penetration into the water column and is a measure of water transparency and therefore an important physical factor influencing phytoplankton growth. The general pattern found for Secchi disc depth is for low values (implying limited light penetration) in the winter and early spring and higher values in the summer and fall. For example, at Pass Manchac (MS1) there was a minimum of 25 cm in February and a maximum of 130 cm in early December. At MS2, the open lake reference station, we observed a minimum value of 40 cm in February and a maximum value of 136 cm in July. Master Station 3, at the IHNC, and MS4, at The Rigolets, had minimum values in April (72 cm and 57 cm, respectively) and maximum Secchi disc depths in November (211 cm and 146 cm, respectively). Master Station 2 might have also had a

maximum value in November except that a shell dredge moved into that area in October and November. Master Station 1 probably has much lower Secchi disc depths than the other stations because of (1) high concentrations of humic substances in water that drains from the extensive wetlands surrounding Lake Maurepas, and (2) the water turbulence within Pass Manchac both of which probably increased the suspended sediment load. The Secchi disc depth is probably related to the seasonal changes in meteorological conditions in which fronts move across Lake Pontchartrain. For example, winter and spring weather fronts cause the bottom sediments to be mixed into the water column, but during summer and early fall, winds blow generally from the south-southeast, probably decreasing the wind-induced mixing of the lake and thus increasing the light penetration into the water.

Linear regressions were made by relating the Secchi disc depth values to the depth at which 1% of the surface light intensity penetrates. Data were based on the type of water masses the stations represented (Table 1). For example, the stations off the Elmwood (S6) and Bonnabel (S7) Canals were combined because they represent locations that often serve as point sources for nutrient enrichment followed by luxuriant growth of the phytoplankton. The results (Table 1) indicate that the strong relationship between Secchi disc depth and the 1% light level depth is variable within Lake Pontchartrain. Inasmuch as the light penetration into the water column depends on the quantities of suspended sediments, chlorophyll concentration in the water, and levels of dissolved substances (such as humic acids) that can absorb light, it is not surprising that different localities in the lake exhibit different patterns in the relationship between Secchi disc depth and the 1% light level depth.

Table 1. The Relationship Between Secchi Disc Depth (cm) and the Level at Which 1% of the Surface Light Penetrates in the Water Column. The Data are for February through November 1978

STATION(S)	r	INTERCEPT	SLOPE
MS1	0.85	-6.22	0.43
MS2	0.45	36.0	0.16
MS3	0.88	28.5	0.31
MS4	0.96	12.3	0.30
S1,S2,S10 S11,S14	0.61	27.9	-0.23
S6,S7	0.87	-13.2	0.45
MS2 S4,S5,S9 S12	0.74	16.6	0.25
MS4,S12,S13	0.95	7.3	0.31
MS1,S3	0.90	-5.4	0.41
MS3,S8	0.88	23.6	0.31

The correlation coefficients are fairly high considering that data were combined for the period February through November.

Figure 2 is an illustration of the relative fluorescence in Lake Pontchartrain during six cruises. A seventh cruise in December is not shown because of the homogeneity across the lake. We assume that the relative fluorescent units (rfu) contoured are representative of plankton biomass since the rfu at different stations is strongly correlated with measurements of chlorophyll _a_ concentrations. On all cruises, rfu is higher near New Orleans than in the open lake. This conspicuous feature is undoubtedly caused by nutrient enrichment via the canals' emptying sewage and street runoff into the lake. We will describe below the major features of each monthly cruise together with the data on assimilation rates (carbon fixed per unit chlorophyll), chlorophyll _a_, and primary production (summarized in Table 2). The conspicuous features of the latter are: (1) the great variation, (2) higher production near New Orleans than in the open lake, and (3) an _in situ_ assimilation rate near the New Orleans canals that was at least 50% greater than that at the other stations. The major features of each cruise are described below.

In April, May, August, and October the lake was fairly smooth during the mapping survey; rough weather in June and July allowed us to complete only half of the planned survey. The December cruise was preceded by rough weather on the lake so that the suspended sediment levels appear to be higher on the first day of the cruise but during the second day of the cruise, the suspended sediment levels appear to be lower. The results of the regression analysis between relative fluorescence and chlorophyll _a_ concentration are presented in Table 3. Good correlation

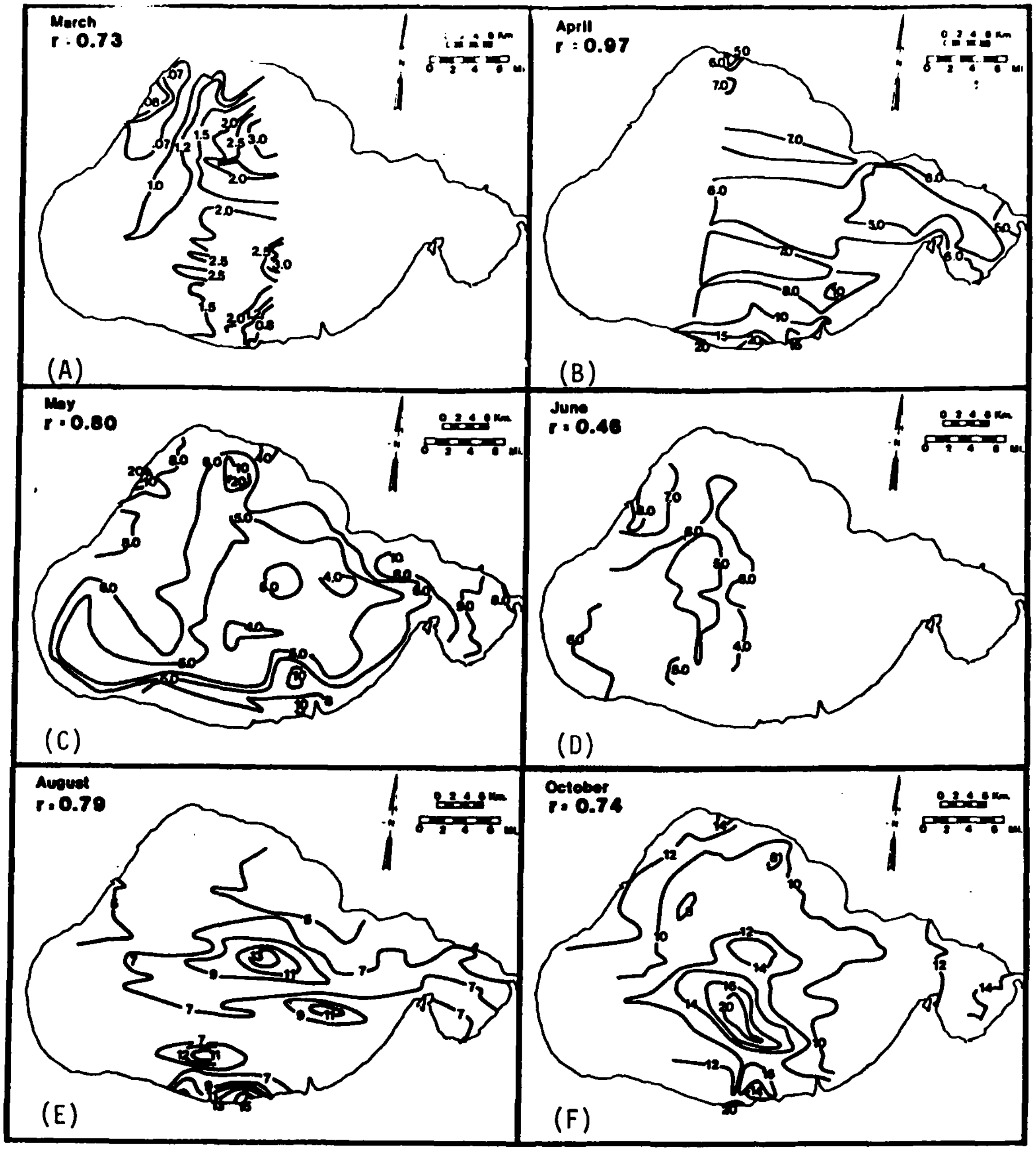

Figure 2. The in vivo fluorescence patterns for six months in 1978 in Lake Pontchartrain, LA. In December the patterns were uniform across the lake and are therefore not shown. (A) March; (B) April; (C) May; (D) June; (E) August; (F) October.

Table 2. Photosynthesis-Chlorophyll Relationships at Master Stations in Lake Pontchartrain, LA; Station MS3 is near New Orleans

Station	*In Situ* C-14 Production [$mgC.m^{-2}.ha^{-1}$]			Euphotic Zone Pigments [mg/m^2]			Assimilation Ratio
	Particulate	Dissolved	Total	Chlorophyll a	Chlorophyll b	Chlorophyll c	
MS 1	20.0	12.2	32.3	15.1	0.47	3.71	2.2
MS 2	35.4	13.9	49.4	29.9	0.44	5.35	1.6
MS 3 (N.O.)	72.6	11.9	84.5	25.5	0.99	6.95	3.3
MS 4	35.6	8.83	44.4	17.8	2.20	6.10	2.6

Table 3. Analysis of the Relationships Between Fluorescence (rfu), Chlorophyll (Chlor) Concentrations, (mg/m^3) and Secchi Disc Depth (cm) for all Stations Sampled

Month	Regression	r	m	b	n
February	Fluor. vs. Chlor.	0.7640	0.2431	6.7405	7
	Fluor. vs. Phaeo.	0.8334	0.7143	6.8498	7
	Chlor. vs. Secchi	-0.8052	-0.2464	14.7919	9
	Fluor. vs. Secchi	-0.9146	-0.1006	11.7654	7
March	Fluor. vs. Chlor.	0.7292	0.4284	6.1380	8
	Fluor. vs. Phaeo.	0.5930	0.2798	9.8482	8
	Chlor. vs. Secchi	-0.1492	-0.1601	15.4232	8
	Fluor. vs. Secchi	0.4392	0.2653	1.1544	7
April	Fluor. vs. Chlor.	0.9743	0.6692	2.2714	16
	Fluor. vs. Phaeo.	0.9171	1.1503	0.5937	14
	Chlor. vs. Secchi	-0.58[illegible]3	-0.9838	66.2216	13
	Fluor. vs. Secchi	-0.5752	-0.6728	47.0933	13
May	Fluor. vs. Chlor.	0.7991	0.3684	3.4246	15
	Fluor. vs. Phaeo.	-0.7315	-0.8076	9.3188	9
	Fluor. vs. Susp. Sed.	0.5738	106.5148	4.2139	11
June	Fluor. vs. Chlor.	0.4624	0.4510	1.4818	10
	Fluor. vs. Phaeo.	0.4632	0.4279	4.0681	10
	Fluor. vs. Susp. Sed.	0.5326	169.4199	4.6150	10

Table 3. (Continued)

Month	Regression	r	m	b	n
July	Fluor. vs. Chlor.	0.3548	0.3598	5.0333	11
	Fluor. vs. Phaeo.	0.7045	0.6012	5.0602	11
	Chlor. vs. Secchi	-0.6592	-0.1104	21.7911	11
	Fluor. vs. Secchi	-0.5672	-0.9633	19.4968	11
August	Fluor. vs. Chlor.	0.7881	0.2752	3.7973	20
	Fluor. vs. Phaeo.	0.6327	0.2800	4.5415	20
	Fluor. vs. Susp. Sed.	-0.2933	-11.4496	6.7985	19
October	Fluor. vs. Chlor.	0.7412	0.7242	7.0528	19
	Fluor. vs. Phaeo.	0.2357	0.1827	11.4647	19
	Fluor. vs. Susp. Sed.	0.1448	53.4490	11.6978	17
	Chlor. vs. Secchi	-0.2486	-0.2719	9.9166	19
	Fluor. vs. Secchi	-0.2320	-0.2480	14.6983	19
	Susp. Sed. vs. Secchi	-0.7630	-0.2284	0.3091	17
December	Fluor. vs. Chlor.	-0.1225	-0.04604	4.5118	20
	Fluor. vs. Phaeo.	-0.2112	-0.1828	4.7196	20
	Fluor. vs. Susp. Sed.	-0.2461	-10.5186	4.3312	18
	Chlor. vs. Secchi	-0.2645	-0.01418	6.2661	16
	Fluor. vs. Secchi	0.8484	0.01191	3.1712	15
	Susp. Sed. vs. Secchi	-0.5140	-0.000136	0.02878	15

Table 3. (Continued)

Month	Regression	r	m	b	n
April 1979	Fluor. vs. Chlor.	0.1317	0.04383	3.09649	17
	Fluor. vs. Phaeo.	-0.4773	-0.3050	6.2887	17
	Fluor. vs. Susp. Sed.	-0.03570	-1.6485	3.5768	17
	Chlor. vs. Secchi	0.07478	0.007981	8.9868	10
	Fluor. vs. Secchi	-0.2917	-0.01290	4.2156	10
	Susp. Sed. vs. Secchi	-0.9138	-0.000834	0.07152	10
Grand	Fluor. vs. Chlor.	0.6866	0.5034	3.0440	143
	Fluor. vs. Susp. Sed.	-0.3235	-73.2107	7.9982	92
	Chlor. vs. Secchi	-0.2917	-0.07031	14.8380	86
	Susp. Sed. vs Secchi	-0.6517	-0.0002454	0.037842	42

(r > 0.7) is found in February, March, April, May, August, and October of 1978; poor correlation occurs in June, July, and December 1978 and in April of 1979. In April of 1979 water with a high suspended sediment load entered Lake Pontchartrain through the Bonnet Carre Floodway. This suggests that rough weather impairs the relationship between *in vivo* fluorescence and chlorophyll *a* concentration. It was thought that the impairment might be caused by suspended sediments coming off the bottom during rough weather. A regression analysis between *in vivo* fluorescence and the dry weight of suspended sediments revealed, however, a very poor correlation coefficient (0.53 to -0.57) that was occasionally negative (Table 3). Thus it is not apparent that variations in suspended sediment level can be simply used to explain the impairment of the *in vivo* fluorescence - chlorophyll *a* relationship during rough weather. In fact, suspended sediment levels do not seem to be related in a consistent manner with the *in vivo* fluorescence levels.

The surface chlorophyll *a* concentrations in February (Fig. 3-A) were uniformly low at all stations except S6 and S7, which are located near the mouths of the Elmwood and Bonnabel Canals, respectively. These two stations are commonly associated with high *in vivo* fluorescence values and probably reflect nearshore nutrient enrichment from Jefferson Parish. The very low assimilation ratios (<1.0 mg C·mg Chl $a \cdot m^{-3} \cdot h^{-1}$ measured in the deck incubator) indicate that both the productivity and biomass are low in the lake in February. In March (Fig. 3-B), the chlorophyll *a* levels were much higher at stations S1, 2, 4, and 5, and at MS2 in the open lake region, about the same as February in the two stations (MS1 and S3) off of the mouth of Pass Manchac and at S6 off the

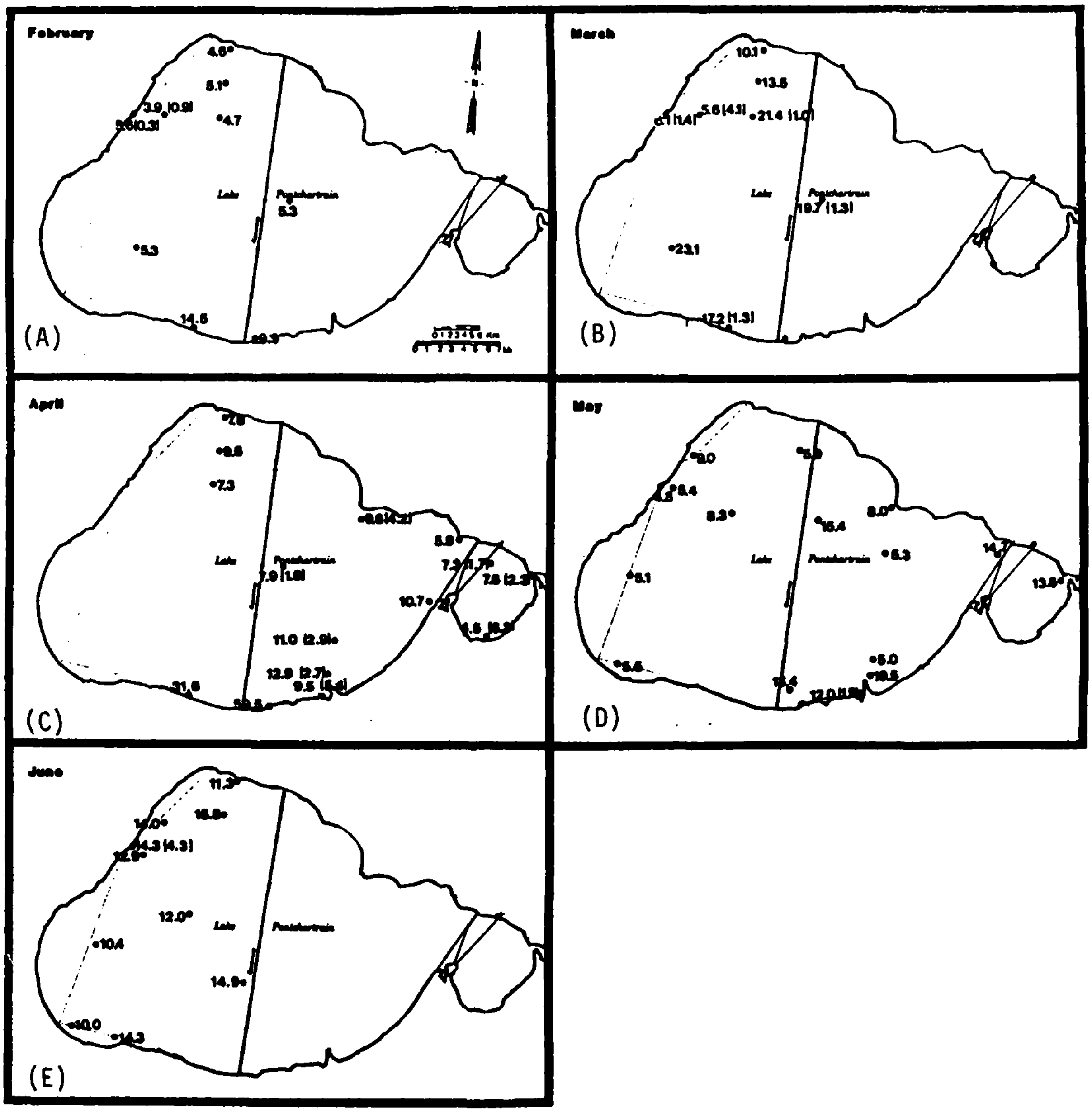

Figure 3A. The measured chlorophyll concentrations (ppb) and the assimilation ratios (in brackets) in the surface waters. (A) February; (B) March; (C) April; (D) May; and (E) June.

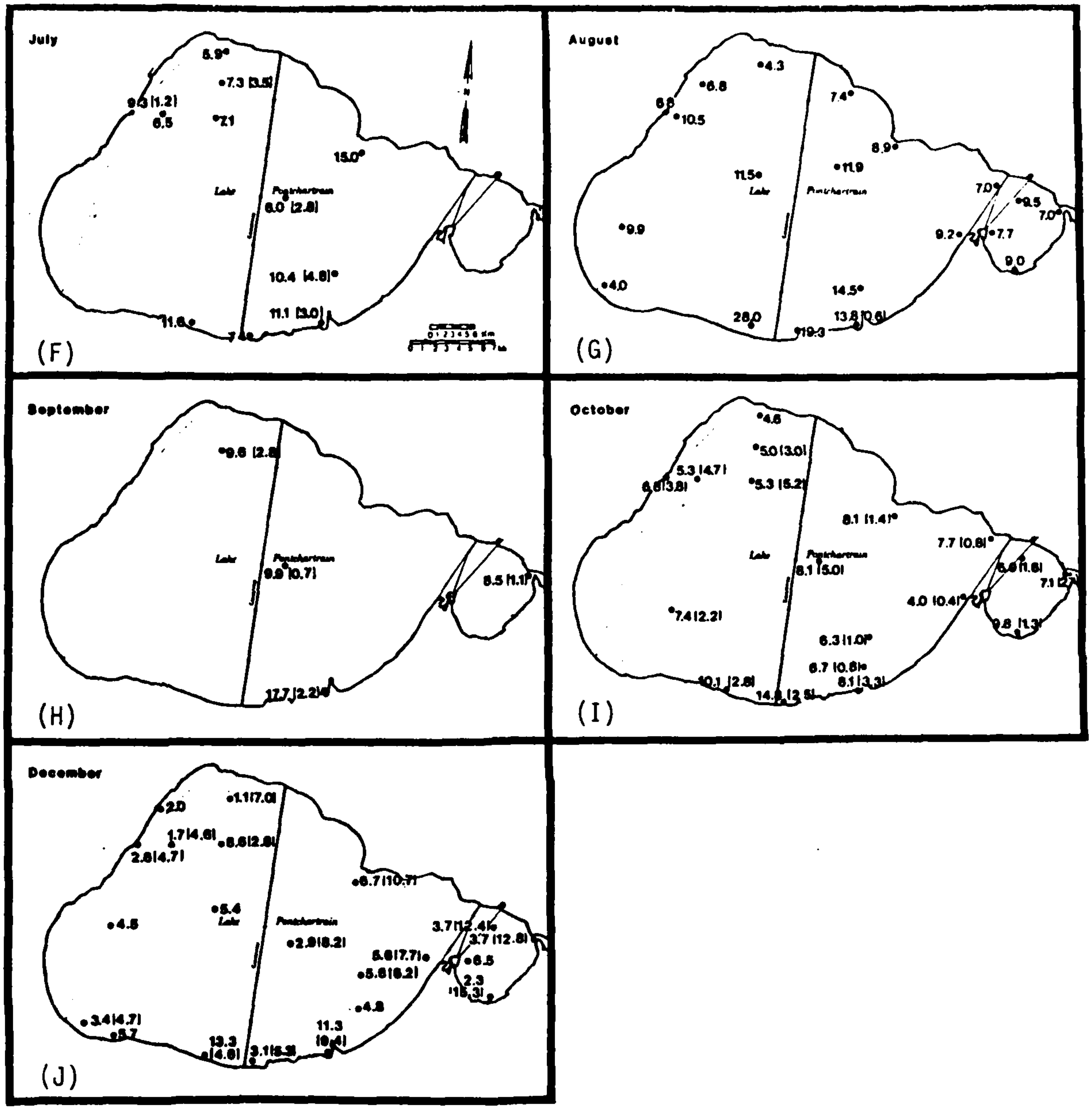

Figure 3B. The measured chlorophyll concentrations (ppb) and the assimilation ratio (in brackets) in the surface waters. (F) July; (G) August; (H) September; (I) October; and (J) December.

Elmwood Canal, and three times as high at S7 off the Bonnabel Canal. The influence of the two drainage canals on the nearshore chlorophyll a levels was apparent. The high chlorophyll levels at the open lake station coupled with the high productivity values at S3, S5, and MS2 suggest that a plankton bloom had occurred in this region of Lake Pontchartrain. The high productivity at S3 coupled with a moderate chlorophyll standing crop suggest that the open lake plankton bloom followed different time sequences in different areas.

The cruise on March 15 was characterized by high biomass water in the center of the lake and low biomass water passing out of Pass Manchac that influenced the water in the western third of Lake Pontchartrain (Fig. 2-A). The phytoplankton biomass appeared to be distributed in a patchy fashion. An illustration of the dynamic nature of the changes in the biomass distribution pattern was observed on a transect from Pass Manchac to the Tchefuncte River mouth on March 17. The *in vivo* relative fluorescence units (rfu) were 7.3 at Pass Manchac, 16.7 at 4.3 km (2.7 miles) out, 6.3 at 5.1 km (3.2 miles) out, 21.2 at 9.5 km (5.9 miles) out, 6.6 at 13.8 km (8.6 miles) out, and 7.9 at the Tchefuncte River mouth. On March 15, no water that exceeded 10 rfu was located along this tract. A high degree of patchiness makes it difficult to extrapolate the results from a few stations to lakewide averages.

The April cruise (Fig. 3A-C) marked our first successful sampling of the eastern half of the lake. Nearshore chlorophyll enrichment was again apparent at S6 and S7, and there were lower chlorophyll values in The Rigolets-Chef Menteur Pass region. Moderate chlorophyll concentrations occurred in the open lake region that had high values during the previous

month. The plankton productivity at MS2 was much lower than that in the region near shore (S10 off of Goose Point) or in The Rigolets-Chef Menteur Pass region (MS4 and S13). The highest productivity occurs in the region adjacent to MS3 or offshore from the IHNC (S8 and S9). The _in vivo_ fluorescence pattern was high along the southern shore in the metropolitan New Orleans area, low off the Tchefuncte River and in the eastern third of the lake, and moderate in the central portion of the lake (Fig. 2-B). The plume near the New Orleans shore appears to have an easterly component. The Bonnabel Canal (S7) has an _in vivo_ fluorescence of 23.7 rfu, which diminished to 8.5 rfu at 6.4 km (4 miles) out to the north.

May (Fig. 2-C) was the first month in which fluorescence on the whole lake was successfully mapped. Areas of high plankton biomass were found off of the Tchefuncte River and just south of the entrance of the Tangipahoa River. The high biomass patch off of the Tchefuncte River was dominated by a surface bloom of the blue-green alga, _Anabaena_. This feature was also located 5.3 km (3.3 miles) off the river mouth on May 19 and 3.9 km (2.4 miles) out on May 26. On May 26, the water conductivity was intermediate between Tchefuncte River water and open lake water (2.45 millimhos/cm). The blue-green algal bloom may have been caught midway between the inshore and offshore salinity gradient in a manner analogous to the trapping of plankton above the thermocline in deeper lakes. On May 26 a high biomass region (32 rfu) was located off the Elmwood Canal (S6) in high salinity (4.11 mmhos/cm) water, but it diminished rapidly offshore in a northerly direction, as indicated by a value of 8 rfu at 2.2 km (1.4 miles) out.

In May, high chlorophyll a (chl. a) levels were found off the Bonnabel Canal, off the IHNC, and in The Rigolets arm of Lake Pontchartrain (Fig. 3A-D). With one exception (15.4 mg/m^3), the open lake chlorophyll concentrations were low, as were those on the western side of the causeway. The assimilation ratio at the IHNC in May was low (1.9), but the station had a moderate productivity value due to the fairly high chl. a level at the station. Rough weather in June permitted sampling only on the western side of the Causeway. The chl. a levels were consistently higher than those found in May (Fig. 3B-F). It appeared that water high in chl. a passed from Lake Maurepas out into Lake Pontchartrain via Pass Manchac (Fig. 2-D). Blue-green algal blooms in Lake Maurepas were very dense then (greater than 20 mg chlorophyll a/m^3) and diminished to 3 mg chl. a/m^3 just offshore from Pass Manchac in Lake Pontchartrain. The high biomass (14.3 mg/m^3) and high assimilation ratio (4.3) at the mouth of Pass Manchac in June reflect blue-green algae passing from Lake Maurepas into Lake Pontchartrain (Fig. 3A-E). Thus, Lake Maurepas appears to be a source of phytoplankton cells for Lake Pontchartrain. The high chlorophyll (16.8 mg/m^3) levels south of the mouth of the Tchefuncte River represent another surface blue-green algal bloom. The offshore lake water had lower biomass (especially near the southern end of the causeway).

In July the chlorophyll concentration at the mouth of Pass Manchac decreased to 9.3 mg/m^3 (Fig. 3B-F) and the assimilation ratio decreased to 1.2, which indicate that the blue-green algae transported from Lake Maurepas into Lake Pontchartrain may be in a less active physiological state. As the June transfer study showed (discussed in a later section of this report), the algal biomass and productivity in Lake Maurepas was

higher then than that at the mouth of Pass Manchac in Lake Pontchartrain. Areas of high productivity and biomass in July include the area off the IHNC; the biomass off the Bonnabel and Elmwood Canals is much lower than the values found in March, April, and May. Moderate biomass and fairly high productivity values occurred at S2 off of the Tchefuncte River and at MS2 in the middle of the lake.

In vivo fluorescence in August (Fig. 2-E) was high off the Bonnabel and Elmwood Canals. Patches of high fluorescence water occurred in the open water of the lake (especially near the Causeway). Low fluorescence water occurred in the northern third of the lake, off Pass Manchac, and in the arm of the lake containing The Rigolets and Chef Menteur Passes. The August chlorophyll concentrations were lower off the Tchefuncte River and at the mouth of Pass Manchac than the values reported in July (Fig. 3B-G). The arm of the lake containing The Rigolets and Chef Menteur Pass had moderate chlorophyll concentrations. Fairly high chlorophyll values were measured at the mouth of and just offshore of the IHNC, but the productivity at MS3 was low and had a low assimilation ratio (0.6). In September the highest chlorophyll *a* concentration and photosynthetic production rate was measured at MS3, which is at the mouth of the IHNC (Fig. 3B-H). Station S2, which is south of the Tchefuncte River, had the highest assimilation ration (2.8) observed in September, but its photosynthetic production rate was only 75% of that observed at MS3 because of the disparity in the standing crops of chl. *a* at each station (9.6 versus 17.7 mg Chl. $\underline{a}$"m^{-3}).

The October cruise marked the first successful effort at completing all 18 stations in the two-day survey cruise. The highest relative fluorescence values were observed off the Bonnabel Canal and in an area

adjacent to the causeway in the southern third of the lake (Fig. 2-F). Shell dredges had moved into the latter area in October. Moderate levels of fluorescence were observed at Pass Manchac, at the mouth of the Tchefuncte River, and near The Rigolets and Chef Menteur Pass. Isolated patches of low fluorescence water occurred in the northern third of the lake near the Causeway. The October data (Fig. 3B-I) are characterized by fairly uniform concentrations of chl. a (with somewhat elevated levels off the Bonnabel and Elmwood Canals and low levels off of South Point) but with widely varying assimilation ratios that suggest that the phytoplankton populations at different localities are in distinctly different physiological states. The region influenced by Pass Manchac seems to have more active plankton populations than that influenced by The Rigolets and Chef Menteur Pass. The region presumably influenced by the IHNC, Bonnabel, and Elmwood Canals appears to have intermediate levels of assimilation ratios. In general the December data are characterized by lower chl. a levels and much higher assimilation ratios in the eastern half of the lake (Fig. 3B-J). For example, at S10 off of Goose Point, the assimilation ratio increased from 1.4 in October to 10.7 in December; that at S13 at the Chef Menteur Pass increased from 1.3 in October to 15.3 in December. The western half of the lake appeared to be more turbid, and the assimilation ratios were generally lower than those found in the eastern half of the lake. The highest chl. a level in December was found off the Elmwood Canal; the highest rate of photosynthetic production occurred off the IHNC. The photosynthesis-irradiance curve constructed for MS1 (which is located at Pass Manchac) that had low transparency indicated that the population was entering into the shade-adapted condition. Since the limited February data indicated both low

chlorophyll a levels and low rates of photosynthesis, our hypothesis is that the system is light limited in the winter.

A transect was run on May 25, 1978, from station MS4 in the mouth of The Rigolets to Station E4 in the middle of Lake Borgne. Table 4 presents an overview of the chemical and biological gradients along this transect. The conductivity is especially low at Station E2 because the sample was taken at the mouth of Little Lake, which receives a large influx of water from the Pearl River. This station was characterized by the highest concentrations for total dissolved phosphorus and total phosphorus. Station E3 was taken off Long Point in Lake Borgne, and the influence of the Pearl River is manifested in the moderate conductivity values and high dissolved silicon concentrations. Station E4 had high concentrations of total dissolved nitrogen, total nitrogen, and total phosphorus when compared with MS4. Master Station 4 was characterized by higher concentrations of total dissolved phosphorus and ammonia. The transect data emphasize the fairly wide range of variation in the chemical and physical factors of the water masses that intermix in The Rigolets and subsequently emerge into either Lake Pontchartrain or Lake Borgne, depending on the tidal cycle and winds. The phytoplankton biomass, as indicated by the chlorophyll a levels, is fairly similar along all stations on the transect, which attests to the effectiveness of the mixing within The Rigolets during the time period under study.

A similar study was conducted on June 21, 1978, between Lake Maurepas and a station three miles (4.8 km) out in Lake Pontchartrain from the entrance to Pass Manchac. Pass Manchac is the major source of freshwater into Lake Pontchartrain and was chosen to provide a different gradient from that existing in the Rigolets-Lake Borgne area. The transect run

Table 4. Chemical Constituents in the Water Along The Rigolets-Lake Borgne Transect (May 25, 1978)

Station	Location Lat. (N); Long. (W)	Conductivity (micromhos/cm)	NH_4 (ppb)	$NO_2 + NO_3$ (ppb)	Total Diss N (ppb)	PO_4 (ppb)	Total Diss. P (ppb)
MS #4-surf	30° 10.5'; 89° 45.3'	2760	50	90	114	20	25
0.5m		2980	64	87	168	32	36
1.5m		2883	37	70	138	14	19
8.0		2710	48	59	214	6	14
E #1-surf	30° 10.5'; 89° 41.2'	1860	81	159	---	--	31
E #2-surf	30° 09.7'; 89° 37.5'	140	28	165	---	--	46
E #3-surf	30° 08.6'; 89° 35.5'	1210	41	173	---	--	28
E #4-surf	30° 03.3'; 89° 35.6'	2710	33	82	535	0	12
2.0m		1320	27	47	---	--	13

Station	SiO_2 (ppb)	Total N (ppb)	Total P (ppb)	Chlorophyll (ppb) a	Chlorophyll (ppb) c	Phaeophytin (ppb)
MS #4-surf	3903	194	34	9.12	3.48	6.41
0.5m	3880	186	44	11.85	3.84	6.01
1.5m	3605	181	37	12.46	5.04	5.58
8.0m	4011	253	40	7.99	3.30	5.29
E #1-surf	4864	---	45	10.15	2.19	11.15
E #2-surf	3863	---	60	8.38	1.10	3.80
[illegible] #3-surf	5083	---	53	9.00	1.28	9.28
E [illegible]-surf	3597	504	52	10.08	2.75	7.74
2.0m	4035	---	33	10.45	---	5.94

from S3 in Lake Pontchartrain to E8 in Lake Maurepas exhibited a steady decrease in conductivity, an increase in dissolved silicon, and a pronounced peak in surface chl. a concentration in Lake Maurepas (Table 5). The chlorophyll a peak represented a surface blue-green algal bloom that was being carried by the tide from Lake Maurepas into Lake Pontchartrain. The sharp drop in chl. a level between the surface and deeper water (2.0-2.5 m) shows that the bloom is confined mostly to the surface. Station E5 is in North Pass near where it joins Pass Manchac and is characterized by low total dissolved phosphorus levels, low dissolved silicon concentrations, and low total phosphorus values. This is probably because it drains through marshes and swamps not subject to anthropogenic activity (thus conserving phosphorus and not being subject to extensive erosion from construction activities). Phaeophytin represents a larger fraction of the active plus degraded chlorophyll pool in the Pass Manchac-Lake Pontchartrain stations than in those stations in Lake Maurepas that are the active region of the blue-green algal bloom. Analysis of a drogue study in July indicated that the water between the surface and 2.5 m is well mixed as it passes through Pass Manchac. This explains the lack of variation of chlorophyll a concentration with depth at S3 when compared to E7 and E8. Station S3 has a lower phytoplankton biomass than E8, but it is interesting to note that the differences in total nitrogen and total phosphorus between the two stations are much less pronounced than the differences in chlorophyll a. This difference can be explain in part by the mixing that occurs as the water passes through Pass Manchac, but it is also probably influenced by an influx of detritus from the wetlands that surround Pass Manchac that augment the total nitrogen and phosphorus levels passing into Lake Pontchartrain.

Table 5. Chemical Constituents in the Water Along an Offshore from Pass Manchac-Lake Maurepas Transect (June 21, 1978)

Station	Location Lat. (N); Long. (W)	Conductivity (micromhos/cm)	NH_4 (ppb)	$NO_2 + NO_3$ (ppb)	Dis. Org. N (ppb)	PO_4 (ppb)	Total Diss. P (ppb)
S #3-surf	30° 17.5'; 90° 14.9'	2760	60	8	398	15	14
2.5m		2600	62	4	401	17	28
E #5-surf	30° 18.0'; 90° 19.4'	2430	58	--			1
E #6-surf	30° 16.9'; 90° 22.3'	1660	96	24			47
E #7-surf	30° 17.0'; 90° 24.3'	1160	39	--			37
2.0m		1250	44	37			32
E #8-surf	30° 17.5'; 90° 28.5'	1110	27	23	610	7	25
2.5m		1070	40	10	576	9	32

Station	SiO_2 (ppb)	Total N (ppb)	Total P (ppb)	Chlorophyll (ppb) a	Chlorophyll (ppb) c	Phaeophytin (ppb)
S #3-surf	1770	558	45	6.45	3.14	3.94
2.5m	1730	483	69	6.53	1.20	5.07
E #5-surf	1550	783	26	7.58	3.64	2.40
E #6-surf	2820	683	90	8.52	----	6.07
E #7-surf	3230	779	61	13.85	1.24	3.60
2.0m	3810	767	60	3.73	----	1.54
E #8-surf	4940	750	64	39.90	2.48	5.81
2.5m	4100	1125	72	12.40	3.20	1.27

Table 6. Average Chlorophyll a Level, Photosynthetic Production and Suspended Sediment Concentration in Surface Water (1978-1979) at Different Stations. Those Stations Near New Orleans are Marked

Station	Chlorophyll a [mg/m^3]			Incubator Particulate Production [$mgC.m^{-3}.hr^{-1}$]			Suspended Sediments [mg. dry wt/ℓ]		
	Avg.	Std. Dev.	n	Avg.	Std. Dev.	n	Avg.	Std. Dev.	n
MS 1	7.4	3.89	10	18.5	16.44	6	13.8	6.66	5
MS 2	8.7	5.01	11	19.4	10.33	9	19.9	9.52	4
MS 3 (N.O.)	10.1	3.53	10	45.2	32.62	8	10.9	6.29	5
MS 4	7.9	2.75	9	25.7	16.80	7	19.1	8.45	5
S 1	6.3	3.29	8				6.2	6.56	4
S 2	9.4	4.04	8	30.7	14.41	4	14.0	11.32	4
S 3	5.1	1.46	8	19.4	11.07	6	26.8	15.26	5
S 4	11.9	9.73	3						
S 5	8.0	4.53	8	24.2	5.44	2			
S 6 (N.O.)	17.4	10.38	8	44.7	22.99	4			
S 7 (N.O.)	19.2	18.40	8	26.1	10.0	3	25.3	22.92	4
S 8 (N.O.)	13.0	5.58	4						
S 9	9.2	2.56	3	29.5	22.08	3			
S 10	9.9	3.32	7	41.3	30.0	3	7.8	3.87	4
S 11	7.9	2.90	5				13.8	16.65	4
S 12	8.2	3.62	5	23.1	19.70	3	10.1	3.97	4
S 13	7.2	3.65	5	25.1	11.09	3	20.2	25.05	4
S 14	6.8	1.27	2						

Some of the results from the *in situ* incubations are shown in Table 2. The yearly average amount of production of dissolved material at four master stations was fairly uniform and ranged from 8.8 to 14 mg $C \cdot m^{-2} \cdot hr^{-1}$. At the IHNC near New Orleans, however, the estimates of particulate production were at least twice as high as at the other three master stations. The assimilation ratio was also higher at station MS3 because there was generally not a corresponding increase in chlorophyll *a* or even chlorophyll pigments *b* or *c*. Examination of the photosynthesis-irradiance experiments in the deckboard incubator showed examples of light adaptation, shade adaptation, and light inhibition at different master stations during the year. There was rarely a simultaneous adaptation to light at all four stations (See Appendixes). Light inhibition occurred only in February and March. Shade adaptation and intermediate shade-light adaptation were generally more common than light adaptation. There were yearly differences, whereas there was a shade adaptation for April 1978. There was a light adaptation in April 1979. The *in situ* photosynthetic measurements exhibited evidence of light inhibition at MS1, MS2, and MS4 between May and July.

The average particulate production (mg $C \cdot m^{-3} \cdot hr^{-1}$), determined in the deck incubator, for each station is given in Table 6. The four stations close to New Orleans have production rates and chlorophyll *a* concentrations higher than that for the other stations. The coefficient of variation is also quite high at all stations, which makes it difficult to interpret the statistical validity of the apparent assumption of differences. It appears that the month-to-month variations in chlorophyll *a* and particulate production are not very great (Table 7), except for the abnormally low levels observed in February. The within-month coefficient of variation is quite

Table 7. Lakewide Monthly Averages and Variability for Chlorophyll a Level, Photosynthetic Production, and Suspended Sediment Concentration in Surface Water (1978-1979)

Month	Chlorophyll a [mg/m^3]			Incubator Particulate Production [mgC.m^{-3}.hr^{-1}]			Suspended Sediments [mg. dry wt/ℓ]		
	Avg.	Std. Dev.	n	Avg.	Std. Dev.	n	Avg.	Std. Dev.	n
February	6.5	3.44	9	2.6	1.48	2			
March	15.4	8.80	9	28.8	14.07	8			
April	13.7	14.19	15	27.2	21.39	3			
May	9.7	4.70	15				24.5	9.68	8
June	13.1	2.16	10	31.0	24.04	2	18.0	6.93	7
July	9.0	2.78	12	26.8	13.69	6			
August	10.4	5.48	20				6.9	3.74	13
September	11.5	3.90	4	22.2	16.62	4			
October	7.4	2.51	18	18.6	11.44	17	8.9	5.81	15
November	8.5	4.96	6	16.4	4.83	3			
December	5.2	3.73	13	39.8	29.57	12	18.4	17.66	15
April 1979	9.9	2.66	13	46.3	21.66	7	33.4	17.92	16

large (often 50%), which underscores the great spatial variation observed within the lake. Disregarding this, however, there are no pronounced seasonal trends in biomass or production for the lake as a whole except in February. There is no single driving force apparent that influences the biomass accumulation or the rate of phytoplankton production within the entire lake as a whole.

There was no obvious vertical stratification of the plankton. In almost every instance, the organisms collected at the 1% light level (relative to the surface) responded to different light levels as did organisms collected at the surface (See Appendixes). However, at MS2 some samples from the 1% light level exhibited a higher assimilation ratio than those samples collected from the surface. In general, the percent production released as dissolved organic matter (DOM) was higher at the lower light levels; the actual amount of dissolved production was greatest at higher light intensities.

EXPERIMENTAL STUDIES

Two experimental studies were designed to investigate the factors influencing planktonic biomass and functional activity in the lake. The transfer studies conducted in May and November at The Rigolets and in June and December at Pass Manchac involved taking organisms from one station and incubating half of them in the water of that station and the other half in water from the other station involved. During the incubation we measured changes in chemical concentrations of the major nutrients and carbon sources and the variation of planktonic biomass and photosynthetic activity over time. The transfer studies were designed to measure the acute response of the organisms to changes in water quality that might

accompany the passage of water masses through the two major passes leading into Lake Pontchartrain.

We also conducted a series of bioassays utilizing natural lake plankton exposed to various nutrient enrichment regimes and observed the resulting patterns of growth in batch culture. In both experiments we filtered the natural plankton through a 145 micron mesh nylon filter by gravity to eliminate effects caused by differential zooplankton grazing.

I. Methods

On May 25, 1978, we conducted an experimental study of the acute responses of organisms passing from Lake Borgne into Lake Pontchartrain via The Rigolets. Surface water was collected at stations E4 and MS4, and the organisms retained by a 10 micron nylon net were separated from their host water. At the time the water was collected, the current was moving from Lake Borgne into Lake Pontchartrain, and the conductivity (micromhos/cm) was 2760 at MS4 and 2710 at E4.

Organisms from The Rigolets (MS4) were then placed in both Rigolets water and water from Lake Borgne. The procedure was the same for organisms from Lake Borgne (E4). This resulted in two experimental bottles (Lake Borgne organisms in Rigolets water and Rigolets organisms in Lake Borgne water) and two control bottles (Rigolets organisms in Rigolets water and Lake Borgne organisms in Lake Borgne water). Selected chemical and biological parameters were sampled at 0, 1, 2, 4, and 6 hours.

The bioassays were conducted in a growth chamber operated at in situ temperatures with a photoperiod of 16 hours light and 8 hours dark at an irradiance level varying between 95 and 185 microeinsteins$\cdot m^{-2} \cdot sec^{-1}$. Two hundred milliliters of lake water were placed in glass flasks and a nutrient enrichment media (1563 μg Si/ml, 77 μg N/ml, 75 μg P/ml, 37 μg

EDTA/ml, 110 μg Vit.b_1/ml, 0.6 μg Vit. b_{12} and biotin/ml, 10 μg Fe/ml, 5 μg Zn/ml, 3 μg Cu/ml, 55 μg Mn/ml, 3 μg Co/ml, 2.5 μg Mo/ml) was added with deletions to each flask. The bioassays utilized those phytoplankton capable of passing a 30 micron nylon net. The basic approach was to compare the growth in a control flask with no nutrient additions to that in a flask with the full complement of added nutrients (the latter being referred to as the "All" treatment). A series of flasks was set up in which one of the added nutrients was eliminated. The level of the deleted element in the natural water sample would then control the growth rate. It was then possible to separate out three types of responses: 1) primary nutrient limitation, in which the growth response is equal to or less than that in the control flask; 2) inhibition, in which the removal of a nutrient stimulates growth significantly greater than the All treatment (suggesting that the level added in the growth stimulating mixture is inhibitory to planktonic growth); and 3) secondary nutrient limitation, in which the rate of decline of a population after reaching maximum chlorophyll levels is greater than the rate of decline in the All treatment. The advantages of this type of bioassay approach is discussed by Smayda (1972). The rate of growth was approximated through the measurement of <u>in vito</u> fluorescence that can be correlated to changes in the chlorophyll levels. Some samples were also fixed for cell counts.

II. <u>Results</u>

The bioassays were conducted in November and December when offshore water had moved into Lake Pontchartrain and had increased salinity at all stations. This was also a period of a rapid decrease in water temperature change (from 22°C to 10°C).

The results of the transfer experiments are summarized in Table 8. The original data are given in the Appendixes. In two of four cases, one in the spring and the other in the winter, organisms from outside of Lake Pontchartrain were stimulated by being mixed with water from the lake. Organisms from Lake Pontchartrain were inhibited by being mixed with water from outside the lake. There was no apparent inhibitory or simulatory response for any of the other combinations of organisms and water.

Nitrogen was the primary limiting nutrient in all bioassays (Table 9). Results from bioassays involving mixtures of water from different stations are given in Table 10. The November experiment provides insight on the potential of Bonnabel Canal water for promoting eutrophication in offshore water masses. The December experiment supports the concept that nitrogen is the primary growth-limiting nutrient but illustrates that factors such as the calcium + magnesium:sodium + potassium ratio may also influence planktonic growth. Our analysis of the water chemistry data suggests possible nitrogen limitation from mid-summer into late fall, which is a period of modest rainfall and prevailing southeast winds that tend to push offshore waters into the lake. Data gathered by the Corps of Engineers and analyzed by the U.S. Geological Survey on the input of inorganic nitrogen to Lake Maurepas from the Amite River and the seasonal nitrite and nitrate concentrations at a station in Lake Maurepas, at Pass Manchac, and at Bayou Lacombe in the eastern end of Lake Pontchartrain are illustrated in Figure 4. As might be expected, the inorganic nitrogen concentrations in Lake Maurepas and Pass Manchac appear to be coupled with the nitrogen input from the Amite River; the Bayou Lacombe inorganic nitrogen concentrations show much less seasonal variation and do not appear tightly coupled to events in Lake Maurepas (the late spring peak at

Table 8. Results of the Transfer Studies

DATE	LOCATION OF TRANSECT	RESULT (PARAMETERS MEASURED)
May 25, 1978	Lake Borgne through The Rigolets into Lake Pontchartrain; surface water source from E4 and MS4	a) organisms from The Rigolets inhibited by water from Lake Borgne (Chl. a, C-14) b) organisms from Lake Borgne stimulated by water from The Rigolets (Chl. a, C-14)
June 21, 1978	Lake Maurepas through Pass Manchac into Lake Pontchartrain; surface water source from S3 and E8	a) *no apparent impact on metabolic* processes (C-14) or biomass (Chl. a)
November 2, 1978	Lake Borgne through The Rigolets *into* Lake Pontchartrain; surface water source from E4 and MS4	a) no apparent impact on C-14 photosynthetic rate b) changes in N:P ratio in incubation water suggests that experimental transfer does not influence nutrient uptake rate
December 14, 1978	Lake Maurepas through Pass Manchac into Lake Pontchartrain; surface water source from S3 and E8	a) no apparent influence on nutrient uptake rate of experimental transfers b) Lake Maurepas organisms stimulated by water from Lake Pontchartrain (assimilation ratio), while Lake Pontchartrain organisms inhibited by Lake Maurepas water

Table 9. Results of the Bioassay Experiments on Nutrient Limitation

	MONTH	STATION	EFFECT	EVIDENCE
1.	November	Lake Borgne (E4)	a) nitrogen limitation b) vitamin and EDTA inhibition	No growth without N Highest growth without these two
2.	November	Rigolets (MS4)	a) nitrogen limitation b) EDTA, vitamins, trace metal are potentially limiting if N supply is adequate	Lower growth than control plants Relative growth curves different without EDTA, vitamins or trace metals
3.	November	Middle of Lake Pontchartrain (MS2)	a) nitrogen limitation	No growth without N
4.	November	In Lake Pontchartrain Near Pontchartrain Amusement Park (E14)	a) nitrogen limitation b) potential trace metal limitation	No growth without N Less stable peak growth than the others (except without N)
5.	November	In Lake Pontchartrain Near Inner Harbor Navigation Canal (MS3)	a) nitrogen limitation	No growth without N
6.	December	The Rigolets (MS4)	a) nitrogen limitation b) chelator limitation	No growth without N Delayed (relative to the others) onset of log growth without EDTA
7.	December	In Lake Pontchartrain Within 4 Km of Pass Manchac (S3)	a) nitrogen limitation	No growth without N

Table 9. (Continued)

	MONTH	STATION	EFFECT	EVIDENCE
8.	December	In Lake Maurepas (E8)	a) nitrogen limitation	No growth without N
			b) potential trace metal limitation	Pronounced lag in growth with N but without trace metals
			c) potential chelator and inhibition	Peak growth response occurred without EDTA or without
9.	December	In Pass Manchac (MS1)	a) nitrogen limitation	No growth without N
			b) potential phosphorus	Low relative growth without P, even with N
10.	December	In Lake Pontchartrain Within 6 Km of Pass Manchac (S5)	a) nitrogen limitation	No growth without N

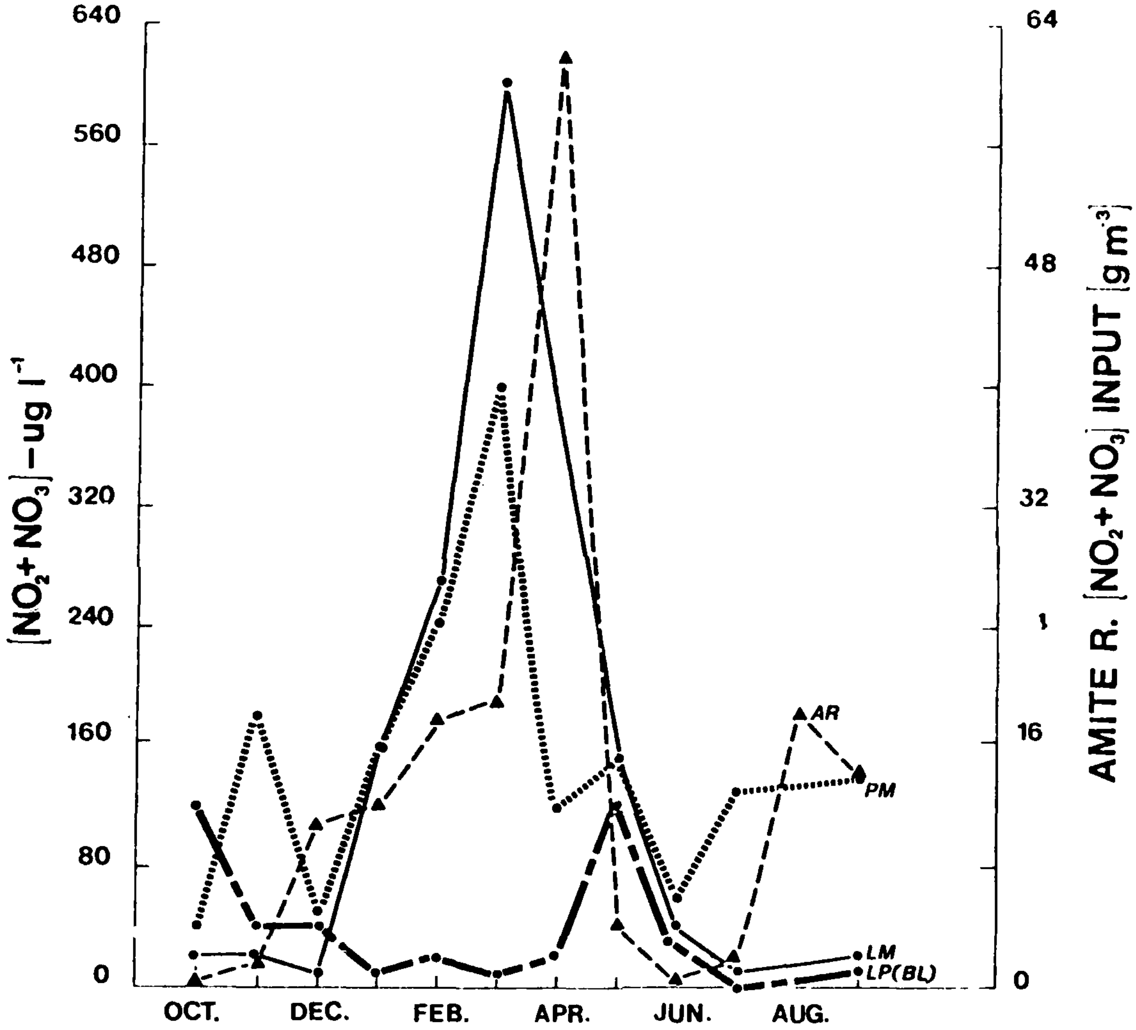

Figure 4. The seasonal changes in nitrate + nitrite as measured by the USGS for the USCOE at four locations in Lake Pontchartrain, LA, in 1977. AR=Amite River; PM=Pass Manchac; LM=Lake Maurepas; LP(BL)=Lake Pontchartrain at Bayou Lacombe.

Bayou Lacombe may represent weak coupling). Inorganic nitrogen concentrations in Lake Maurepas exhibit wider fluctuations than those at Pass Manchac, which suggests that either the lake sediments or biota in the wetlands tend to dampen fluctuations in the nitrogen flux passing through Pass Manchac into Lake Pontchartrain. The drainage canals emanating from the metropolitan New Orleans area are another important nitrogen source, but we lack information on the water discharge rates from these canals, which precludes quantitative assessment of their nitrogen input. It is possible that phosphorus may limit algal growth in the late spring and early summer, but we lack hard data at present to make a definitive statement on this matter.

III. Discussion

The phytoplankton community in Lake Pontchartrain is characterized by temporal and spatial variability as the organisms respond rapidly to changes in their environmental milieu. In Tables 6 and 7, the chlorophyll *a*, incubator primary production, and suspended sediment data have been collected on a monthly basis or on a station basis to facilitate the discussion of temporal or spatial trends. The large standard deviation (in comparison to the mean values) is a reflection of the spatial (Table 7) and temporal (Table 6) variability. The coefficient of variation (standard deviation ÷ [mean x 100]) for the chlorophyll *a* data averages 48.9 for the 12 months listed in Table 7 and 47.3 for the 18 stations listed in Table 6. This suggests that the spatial and temporal variability are of comparable magnitude. In this section we will indicate the trends in Tables 6 and 7 and then discuss some ideas of why these trends occur. The final question to be addressed is: Why do the data have such a high degree of temporal and spatial variability?

It is apparent that peak chlorophyll a concentrations occur in March, April, and June and that the lowest values occur in December and February (Table 7). The spring chlorophyll peak is probably caused by increased diatoms abundance; the June peak features green and blue-green algae as important components (cf. Chapter 8). The potential photosynthesis (measured in the deckboard incubator) exhibited peak production in December and April of 1979 and minimal values in February. The suspended sediment concentrations are lowest in late summer and early fall; the highest values occur in the spring. No winter samples were collected for suspended sediments, but the Secchi disc depth readings at this time of year indicated that water transparency was at a minimum. Since water transparency is correlated with suspended sediment concentration, it is suggested that suspended sediment levels probably reach the yearly maximum in the winter. The driving force for the variation in the suspended sediment level is probably wind power, which reaches maximal values in December and January and minimal values in July and August (cf. Chapter 3, Gael).

The photosynthesis-irradiance curves, constructed from experiments in the deckboard incubator, exhibit signs of photosynthetic inhibition at higher light intensities in February and March, which suggests that the phytoplankton in Lake Pontchartrain are light limited at this time. The rapid increase in water temperature (7°C to 19°C at the surface) between February and March probably stimulates planktonic growth. This coupled with the relatively high concentrations of total inorganic nitrogen (TIN) and orthophosphate (DIP) in the water probably account for the chlorophyll maximum during spring. In other pelagic systems, zooplankton grazing becomes more effective as the spring diatom bloom progresses and results in diminished chlorophyll levels in the late spring. Unfortunately we

have no measure of the intensity of zooplankton grazing upon the phytoplankton.

One technique for examining potential nutrient limitation of phytoplankton growth is to calculate the ratio of total inorganic nitrogen (NH_4^+ + NO_2^- + NO_3^-) in the water to that of orthophosphosphate (PO_4^{-3}) and to compared this with the particulate nitrogen to particulate phosphorus ratio in the seston (living and nonliving organic matter). The rationale for this approach is discussed by Ryther and Dunstan (1971) and Goldman (1976); the problems inherent in this type of analysis are covered by Banse (1974). The extensive wetlands surrounding Lake Pontchartrain make it likely that the seston will be dominated by nonliving organic matter rather than plankton (cf Chapter 8). The following discussion will focus on the nitrogen-phosphorus (N:P) atomic ratio in the water and seston.

In the May transfer experiment between Lake Borgne and The Rigolets, the N:P ratio in Lake Borgne water was 19.8 and that in The Rigolets was 12.4; in the seston, the N:P ratio was 21.4 in Lake Borgne and 10.8 in The Rigolets. During the 6-hour incubation period, the N:P ratio in the water increased to 957.8 when Rigolets organisms were placed in Lake Borgne water and to 105.4 when Lake Borgne organisms were placed in Lake Borgne water. This increase in the N:P ratio in the Lake Borgne water suggests that phosphorus was taken up preferentially over inorganic nitrogen and that the organisms were phosphorus limited. The Rigolets organisms appear to be more phosphorus limited than those from Lake Borgne because of the larger increase in the N:P ratio in the water after the 6-hour incubation period. From the start to the end of the 6-hour incubation period for Rigolets water, the N:P ratio increases 2.7 fold when Lake Borgne organisms serve as the innoculum and 5.1 fold when Rigolets organisms serve as the

innoculum. This supports the arguments that phosphorus is taken up preferentially to nitrogen and that The Rigolets organisms are more severely phosphorus limited than organisms from Lake Borgne. A crude generalization is that nitrogen is likely to be limiting if the N:P ratio in the water is less than 10, and phosphorus is likely to be limiting if the N:P ratio is greater than 20. From the foregoing generalization, one would predict that Lake Borgne water is more likely to be limited in phosphorus than Rigolets water. When the phosphorus-limited Rigolets organisms are placed in Rigolets water, they have a higher assimilation ratio than Rigolets organisms innoculated into Lake Borgne water. Our observations verify the prediction. This illustrates that the nutrient status of the organism plays a role in nutrient limitation as well as the N:P ratio in the water.

At the stations influenced by water emanating from the Metropolitan New Orleans region (MS3, S6, and S7), the N:P ratio in the water is less than 5 at all times of the year. This ratio is in keeping with the observed trend that coastal water near large population centers have an N:P ratio similar to that of treated and untreated wastewaters that have an N:P ratio of 5 (Goldman 1976). Such an N:P ratio would imply that the system is nitrogen limited. Water collected from S7 on November 20, 1978, for a bioassay exhibited rapid growth of phytoplankton even without any nutrient additions, which can be explained by a total inorganic nitrogen (TIN) concentration of 28.36 μg-at./ℓ and a dissolved inorganic phosphorus (DIP) concentration of 5.87 μg-at./ℓ. This corresponds to an N:P ratio in the water of 4.8. When water from S7 was mixed in various dilutions with nitrogen-limited, offshore water from MS2, it stimulated the growth of MS2 organisms even at 199-to-1 dilutions. The TIN concentrations of S7 was 66 times that found at MS2. A similar comparison of chlorophyll a levels

Table 10. Results of Bioassays Involving Mixtures of Organisms and Water from Different Stations

MONTH	STATION COMBINATION	EFFECT	INTERPRETATION
1. November	Middle of Lake Pontchartrain (MS2) and Bonnabel Canal (S7)	MS2 control- no growth	limited by nitrogen
		S7 control- rapid growth and largest chlorophyll a standing crop	not limited by nutrients; possible light limitation
		Addition of S7 water to MS2 water resulted in some growth at 199:1 dilution and more extensive growth than All treatment at 19:1 dilution	growth of MS2 organisms stimulated by high nutrient levels in S7 water (TIN = 387 ug/l; TDP = 203 ug/l) rather than the added increment of phytoplankton in S7 water; S7 water contained adequate levels of other growth factors
		Addition of MS2 water to S7 water resulted in lower chlorophyll a standing crops; maximum growth rates at 1:4 dilution	greatest yield in S7 control with decreasing yields with addition of increasing amounts of MS2 water; maximum growth rate at intermediate dilution suggests possible light or toxic material inhibition in S7 control;
		Phytoplankton levels in the field at S7 are 3 times greater than levels at MS2, while laboratory bioassay suggests that growth potential at S7 is 160 times that at MS2	chlorophyll a levels at S7 in the field controlled by additional factors besides nutrient concentrations (zooplankton grazing and stability of water column)

Table 10. (Continued)

MONTH	STATION COMBINATION	EFFECT	INTERPRETATION
2. December	Middle of Lake Maurepas (E8) and 4 km off Pass Manchac in Lake Pontchartrain (S3)	E8, S3, and E8-S3 mixtures exhibited no significant growth	limited by same nutrients
		1:1 mixture of E8 and S3 + All exhibited good growth 30 hour lag period	lag period attributed to preference of phytoplankton for a chemical milieu richer in calcium and poorer in potasium and sodium; All mixture satisfy nutrient deficiency
		Nutrient spike experiment showed good growth of E8 S3 water after nitrogen addition; trace metal addition stimulated growth in E8 water; no effect of spikes of phosphorus, silicon and vitamin + EDTA	nitrogen is primary growth limiting nutrient at both E8 and S3; trace metals possibly also limiting at E8; other additions are not limiting at this time

shows that S7 has 3 times the phytoplankton biomass levels found at MS2. This suggests that the chlorophyll a biomass found in situ at S7 is controlled by factors other than nitrogen limitation. Possible factors include inhibition of phytoplankton growth by heavy metals, zooplankton grazing, or vertical water mixing removing phytoplankton from the euphotic zone.

The N:P ratios in the water at MS1 change seasonally. They were higher in March-May and lowest during October-December. The March-May N:P ratio at MS1 (22.7) and MS4 (19.8) suggests the possibility of phosphorus limitation of phytoplankton growth. Both of these stations receive significant freshwater discharges (via Pass Manchac for MS1 and the Pearl River for MS4) in the winter and early spring that tend to have a high N:P ratio. The N:P ratio at MS2 during March-May is 8.8, which is more characteristic of nitrogen-limited systems. During the June-September period, the N:P ratio in the water is less than 5 at MS2 and MS4 but is still fairly high at MS1 (16.8). This suggests that MS2 and MS4 are nitrogen limited. The N:P ratio in the water is less than 10 at all of the master stations during the period from October-December. During this period, the N:P ratio varies from a high of 7.4 at MS1 to a low of 1.1 at MS3. The N:P ratios in the water then imply that the system was nitrogen limited, a fact demonstrated in the nutrient deletion bioassays carried out in all parts of Lake Pontchartrain between October and December.

It is suggested that this general seasonal decrease in the N:P ratio is governed by meteorological factors that control the major sources of nutrient input and saltwater intrusion from the Gulf of Mexico, freshwater inflow through the rivers and Pass Manchac, nutrient additions from the sediments, and enrichment from the Metropolitan New Orleans area. The N:P ratio in the water at The Rigolets (MS4) is inversely correlated with conductivity (r = 0.903), which suggests that the intrusion of offshore

water brings in water low in nitrogen (relative to the phosphorus concentration). The water entering at Pass Manchac (MS1) has a higher N:P ratio at all seasons than the other master stations, which indicates that the freshwater inputs tend to be lower in phosphorus than in nitrogen. Water emanating from the metropolitan New Orleans area has an N:P ratio less than 5. In the winter and early spring, fronts move through Louisiana and result in frequent storms and rainfall that is converted into river runoff. This results in an input of water with a high N:P ratio into Lake Pontchartrain and makes possible phosphorus limitation of phytoplankton growth (in addition to previously mentioned factors of light limitation and zooplankton grazing). A high pressure zone forms in the Gulf of Mexico in the summer and early fall that prevents fronts from moving across southern Louisiana and results in the generation of convective thunderstorms. The prevailing winds are from the south and push higher conductivity, lower N:P ratio water from the Gulf of Mexico into Lake Pontchartrain. The high evapotranspiration during this period makes the conversion of rainfall to river runoff less effective and reduces the nutrient input from rivers and from the drainage canals emptying the Metropolitan New Orleans area. The gentle prevailing winds during the summer and early fall result in greater water transparency because of lower suspended sediment levels. Even though the majority of the photosynthesis-irradiance curves are of the shade-adapted variety, light-adapted curves were more prevalent from June to early October, which was the period of greatest water transparency. The most favorable light regime for phytoplankton growth occurs in July, when the water transparency is high (deep euphotic zone) and the solar radiation is just past its June maximum. The lack of storms would also result in less transfer of nutrients from the sediments to the water

column. All of these factors combine to produce a nitrogen-limited planktonic community in the late summer and fall.

One characteristic of the planktonic system in Lake Pontchartrain that is not explained in the foregoing analysis is the increase in the assimilation ratio between early October and either early November or mid-December (Fig. 3B-I and 3B-J). One consequence of the increased assimilation ratio is that the low December phytoplankton standing crop supported the second highest observed monthly primary production values (in the deckboard incubator). One hypothesis (that is not testable with the data at hand) is that zooplankton grazing was responsible for decreasing the chlorophyll _a_ levels from 8.5 mg/m^3 in November to 5.2 mg/m^3 ıı December (cf Chapter 8). The zooplankton greater than 145 microns were removed prior to the photosynthetic measurements in the deckboard incubator, so that differential zooplankton grazing would not influence the results. Thus, the potential production doubled between October and December for the lake as a whole in the absence of significant zooplankton grazing. Examination of the N:P ratio and actual concentrations of TIN and DIP show that only at MS1 can an increase of nutrients be used to explain the December increase in assimilation ratio. At stations MS2 and MS4, the N:P ratio, TIN concentration, and DIP concentration actually decreased during the period when the asimilation ratio increased, but at MS3 these parameters did not change during the period when the assimilation ratio rose. The photosynthesis-irradiance curves in November and December are all of the shade-adapted variety, so the light adaptation of the phytoplankton is not likely to account for the higher rates of potential photosynthetic production. Thus, the cause of the increase in assimilation ratio at MS2, MS3, and MS4 in the late fall has not been elucidated. The maximum _in situ_ primary

production at MS2 and MS4 occurs in November, which suggests that the incubator results of potential production are not experimental artifacts.

An examination of Table 8 reveals that the maximum chlorophyll a concentrations occur at S6 and S7 and that the highest rates of potential primary production occur at MS3, S6, and S10. The nutrient enrichment from the metropolitan New Orleans region probably accounts for the relatively high standing crop biomass and photosynthetic production at S6, S7, and MS3 (Elmwood, Bonnabel, and IHNC, respectively). Station S10 is off Goose Point and may represent a response to nearshore conditions or to the presence of submerged grassbeds. In general, primary production is more responsive to eutrophication than is the standing stock of chlorophyll a. An example of this can be seen in Table 2 where the *in situ* primary particulate production at MS3 is 72.66 $mgC \cdot m^{-2} \cdot hr^{-1}$ compared to 35.41 $mgC \cdot m^{-2} \cdot hr^{-1}$ at MS2, and the chlorophyll a concentration is actually higher at MS2 (29.96 mg/m^2) than at MS3 (25.54 mg/m^2). As a consequence, the assimilation ratio for the euphotic zone for total production is 3.3 at MS3 and 1.6 at MS2. *In situ* primary production results indicate that at the two fresher stations (MS1 and MS2), the dissolved production is 33% of the total production, but at the more saline stations (MS3 and MS4), dissolved production is 17% of the total production. The literature suggests that dissolved production in eutrophic systems is higher than that in oligotrophic waters but that the reverse is true for dissolved production as a percentage of the total production (Berman and Holm-Hansen 1974). In Lake Pontchartrain, the dissolved production in an absolute sense is similar at all of the master stations and varies from 8.83 mgC/m^2 hr at MS4 to 13.99 mgC/m^2 hr at MS2. The dissolved production as a percentage of the total is comparable at MS1 and MS2, in spite of the

fact that MS1 is characterized by the highest average TIN and DIP concentrations and MS2 is characterized by the lowest concentrations among the four master stations. Although the average nutrient concentrations is high at MS1, the _in situ_ production is the lowest among the four master stations. There are at least two reasons: the water transparency is less than at the other four master stations, and one of the _in situ_ incubations was carried out on an overcast day, which would result in a low estimate of the primary production.

The hourly _in situ_ primary production values were converted to daily values by comparing the radiant energy impinging on the sea surface during the incubation period with that occurring between sunrise and sunset. This approach assumes that the daily primary production is directly related to the incident solar radiation. For a shallow, turbid system such as Lake Pontchartrain, without vertical gradients in nutrient concentration or phytoplankton biomass, this appears to be a reasonable assumption. The _in situ_ particulate production at MS2, MS3, and MS4 is closely correlated with the surface particulate production in the deckboard incubator ($r = 0.860$). The _in situ_ particulate and total primary production were converted to a yearly estimate by comparing the seasonal trend of the daily _in situ_ values with the trend in the surface values in the deckboard incubator. A factor was used to make this conversion for the time period during which both _in situ_ and deckboard incubator primary production estimates were made. The deckboard incubator provided estimates of potential primary production for the whole year that allow one to extrapolate the _in situ_ measurements to a yearly basis by comparing the potential production from the spring to late fall with the results from the whole year. Such an approach has produced estimates of _in situ_ production ($gC \cdot m^{-2} \cdot yr^{-1}$) of:

95.0 (particulate) and 124.4 (total) for MS1; 110.4 (particulate) and 146.1 (total) for MS2; 187.2 (particulate) and 235.5 (total) for MS3; and 107.8 (particulate) and 124.1 (total) for MS4.

Here we compare this with other primary production measurements in Louisiana. Sklar (1976) obtained an estimate of 260 $gC \cdot m^{-2} \cdot yr^{-1}$ for water in the Gulf of Mexico 10 km from shore; Hopkinson and Day obtain values (gC ($gC \cdot m^{-2} \cdot yr^{-1}$) of 625 for Lake Cataouatche, 311 for Little Lake, and 212 for Lake Salvador. These workers only measured particulate primary production and used different procedures for converting hourly in situ production to yearly estimates. The Lake Pontchartrain data for a yearly production estimate using Hopkinson's approach give a range for particulate production from 72-269 $gC \cdot m^{-2} \cdot y^{-1}$, and our data using Sklar's approach give a range for particulate production from 88-318 $gC \cdot m^{-2} \cdot y^{-1}$ (average = 179). These comparisons suggest that primary production in Lake Pontchartrain is on the low side of what one would expect for unpolluted planktonic systems in Louisiana (nearshore in Gulf of Mexico or Lake Salvador). Lake Cataouatche represents an extremely eutrophic system, and Little Lake represents an extremely mesotrophic system. An extensive review of annual primary production by Platt and Subba Rao (1973) was consulted to obtain an average of 155.3 $gC \cdot m^{-2} \cdot yr^{-1}$ for a collection of 22 nearshore coastal systems and embayments spread throughout the tropical and temperate oceans of the world. The annual production for Lake Pontchartrain is near this average value. The annual primary production ($gC \cdot m^{-2} \cdot y^{-1}$) for some representative coastal embayments (Platt and Subba Rao 1973) includes: Baltic Sea (35-74); Mediterranean (75); Pamlico Sound, North Carolina (100); lower Chesapeake Bay (365); upper Chesapeake Bay (73); Gulf of Panama (180); St. Margarets Bay, Nova

Scotia (190); Departure Bay, British Columbia (200); Bedford Basin, Nova Scotia (220); and Long Island Sound (380). One would expect that the subtropical systems in Louisiana would have fairly high levels of annual primary production because they lack the seasonality in photosynthetic rate characteristic of temperate systems and the severe nutrient limitation of tropical regions. The high turbidity in Lake Pontchartrain results in a shallow euphotic zone that probably decreases the annual primary production in spite of a uniform rate of potential photosynthesis from March through December.

There appears to be no single explanation for the spatial and temporal variability that exists in either the planktonic structure or activity in Lake Pontchartrain. Seasonal variations in N:P ratios at the four master stations illustrate the fact that the stations lie on different parts of the nutrient input gradients from the major nutrient sources: Lake Borgne, Metropolitan New Orleans, river runoff, and sediments. Since the inputs from these major nutrient sources have somewhat different temporal sequences and the actual spatial gradients would be established in different directions, one would expect an environmental mosaic to occur that would result in the patchy plankton distribution. Superimposed upon these seasonal phenomena are storm events that can influence nutrient availability and physically transport plankton out of the euphotic zone. Rainfall associated with storms may be a source of nitrogen that appears to be the limiting nutrient in the system in the late summer and fall. The increase in the TP and $NO_2 + NO_3$ concentration in the lake appears to be correlated with heavy rainfall in the New Orleans metropolitan region in August. The types of organisms making up the plankton change seasonally due to variations in temperature and

nutrient concentrations. Light availability and water transparency are important environmental controls on planktonic activity. Zooplankton density in Lake Pontchartrain are much lower than those reported in either Lake Borgne or the Vermilion Bay-Atchafalaya Bay complex (Tarver and Savoie 1974; cf Chapter 8). Differential grazing by zooplankton on the phytoplankton may not play an important role in structuring the planktonic community in Lake Pontchartrain, but we lack information on zooplankton feeding rates to test this hypothesis. It appears that the phytoplankton in Lake Pontchartrain are predominately controlled by physical and chemical environmental factors. Changes in either the lake itself or in the surrounding watershed is likely to result in a rapid response of the planktonic system if a key environmental control variable is influenced. Because the plankton in the lake are a pulsed community, they are likely to accommodate themselves rapidly to such changes. Whether such accommodations are considered detrimental depends on the prevailing water quality criteria and the impact of altered plankton composition on fish and shellfish food webs.

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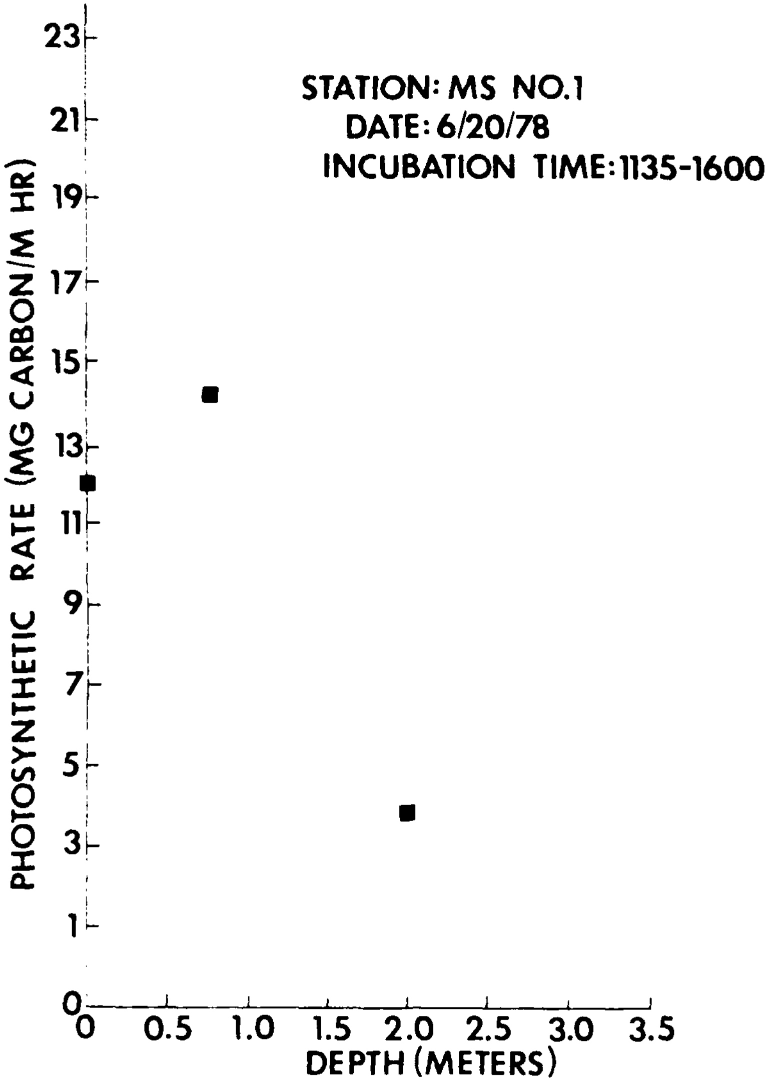
Camps near Chef Menteur Pass

APPENDIX 1

Productivity Data

The results of the productivity experiments wherein samples were incubated either *in situ* (left side of the diagram) or in an incubator (right side of the diagram). The former were samples from the depth at which they were incubated. The latter were collected from either the surface or deeper and incubated under a variety of light conditions. The sampling station and date are indicated in each figure.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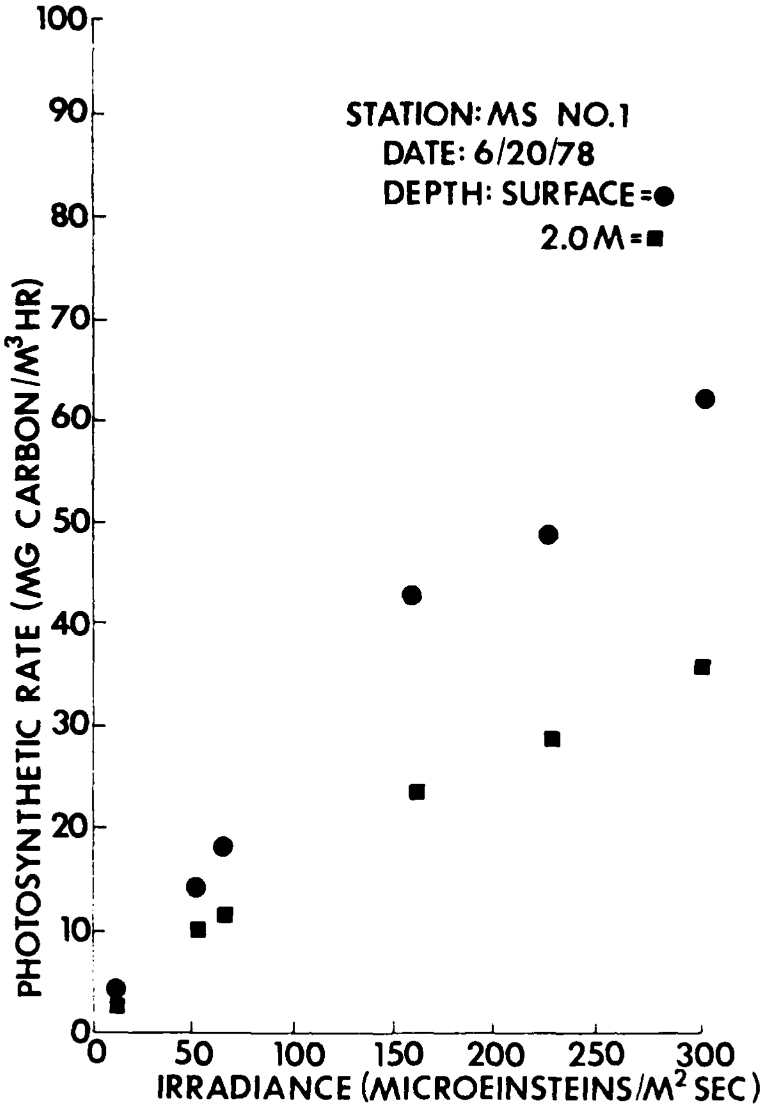
INCUBATION TIME: 1135-1600
PHOTOSYNTHETIC RATE (MG CARBON/M HR)
23
21
19
17
15
13
11
9
7
5
3
1
0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
DEPTH (METERS)


STATION: MS NO.1
DATE: 6/20/78
DEPTH: SURFACE=●
2.0M=■
PHOTOSYNTHETIC RATE (MG CARBON/M³HR)
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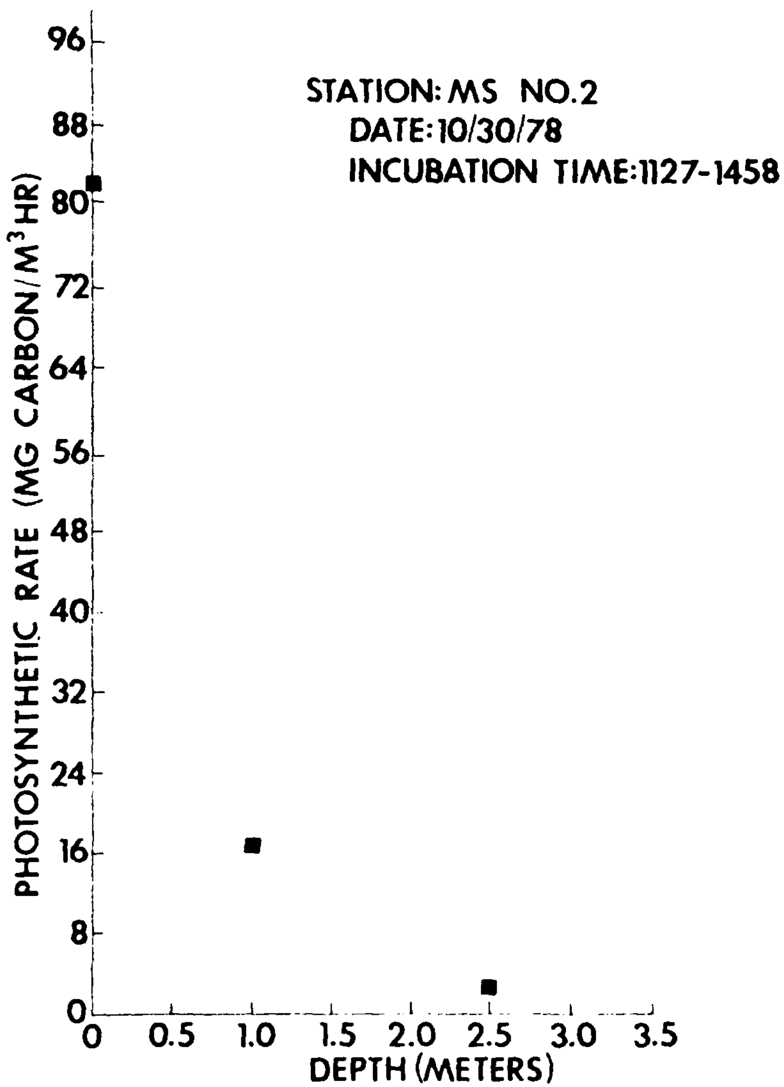
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
IRRADIANCE (MICROEINSTEINS/M² SEC)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DATE: 10/30/78
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PHOTOSYNTHETIC RATE (MG CARBON/M³HR)
DEPTH (METERS)
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88
80
72
64
56
48
40
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16
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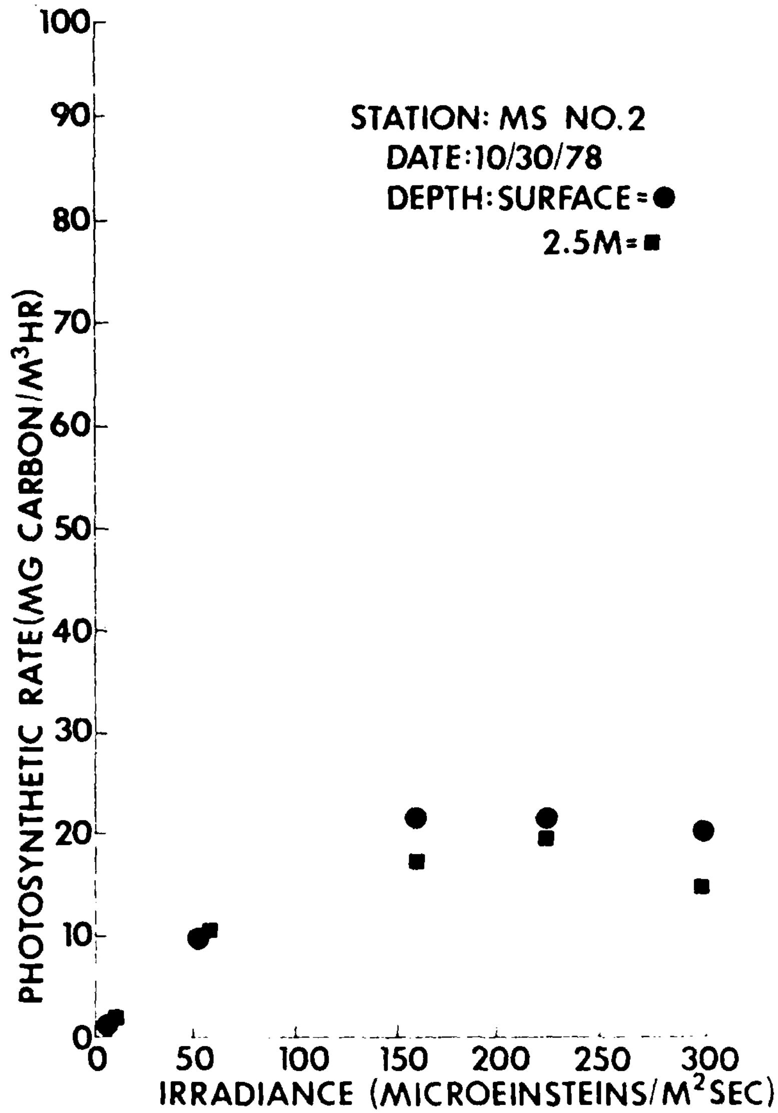
3.5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2.5M = ■
PHOTOSYNTHETIC RATE (MG CARBON/M³HR)
IRRADIANCE (MICROEINSTEINS/M²SEC)
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80
70
60
50
40
30
20
10
0
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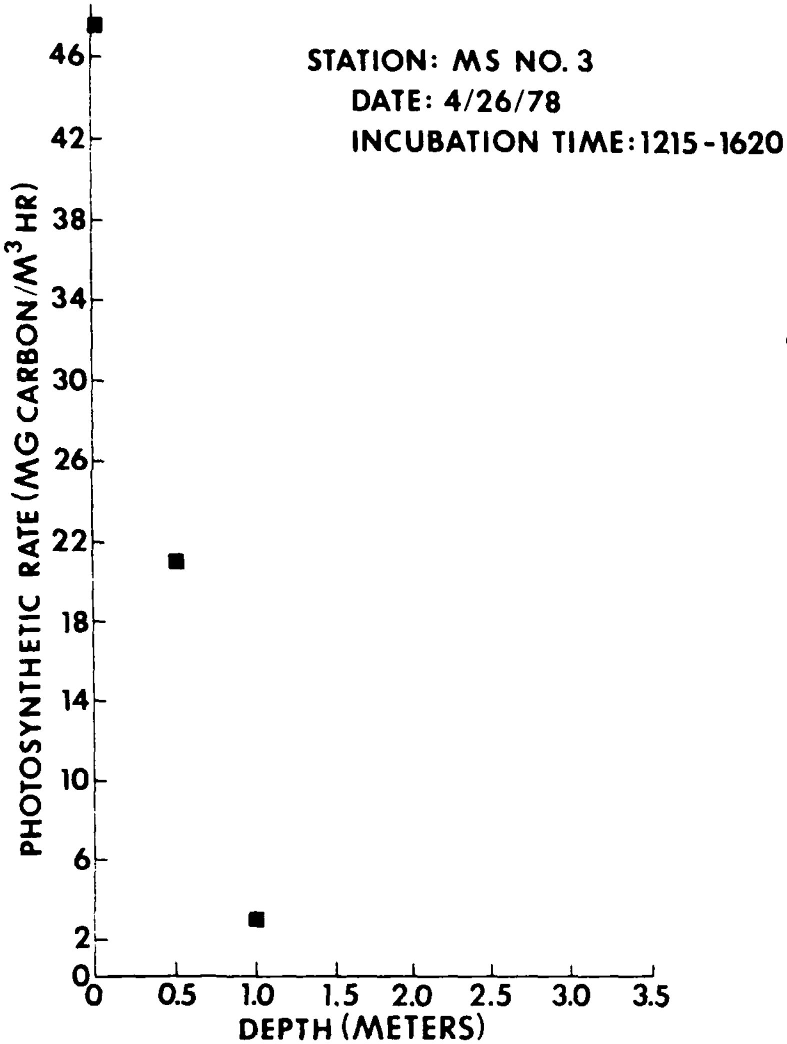
50
100
150
200
250
300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DATE: 4/26/78
INCUBATION TIME: 1215-1620
PHOTOSYNTHETIC RATE (MG CARBON/M³ HR)
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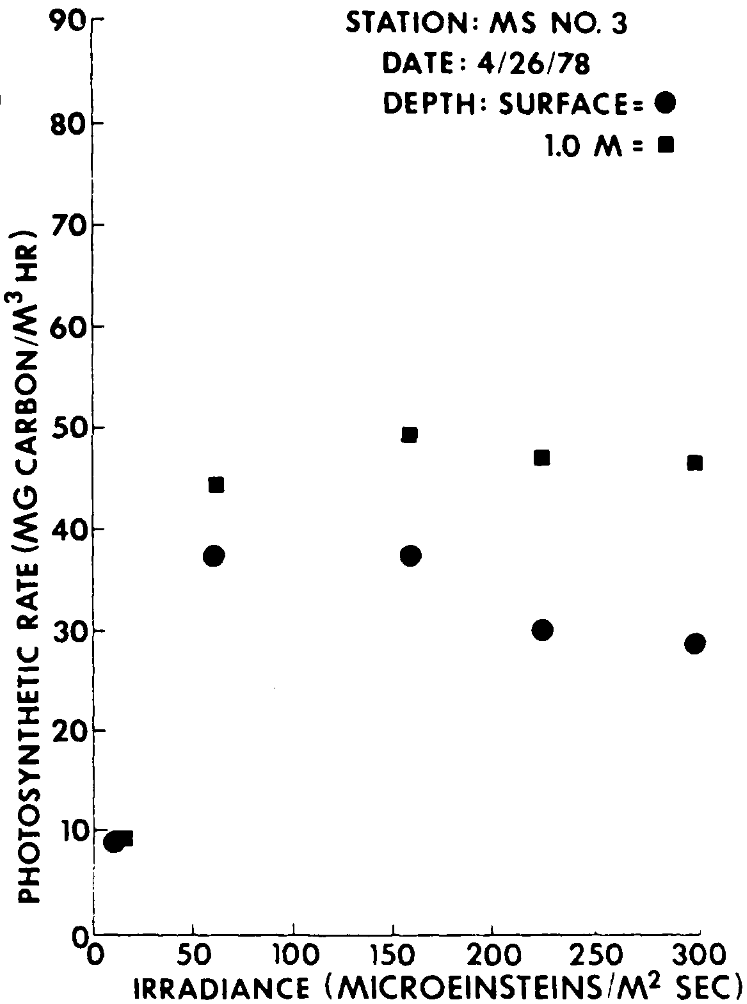
42
38
34
30
26
22
18
14
10
6
2
0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
DEPTH (METERS)


STATION: MS NO. 3
DATE: 4/26/78
DEPTH: SURFACE =
1.0 M =
PHOTOSYNTHETIC RATE (MG CARBON/M³ HR)
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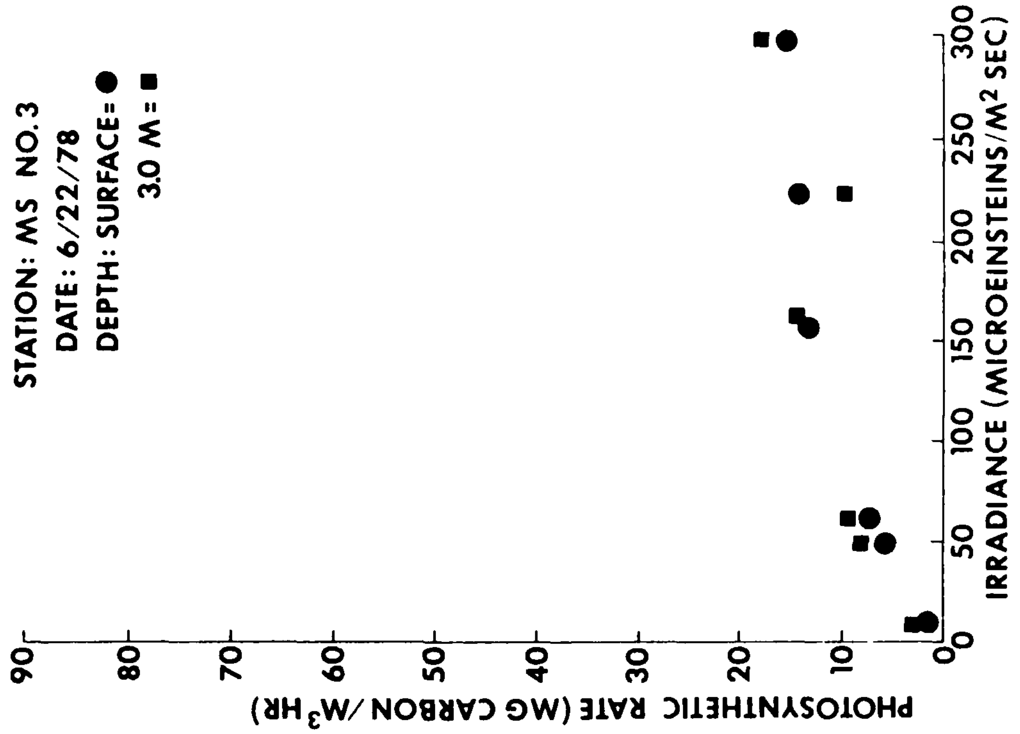
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
IRRADIANCE (MICROEINSTEINS/M² SEC)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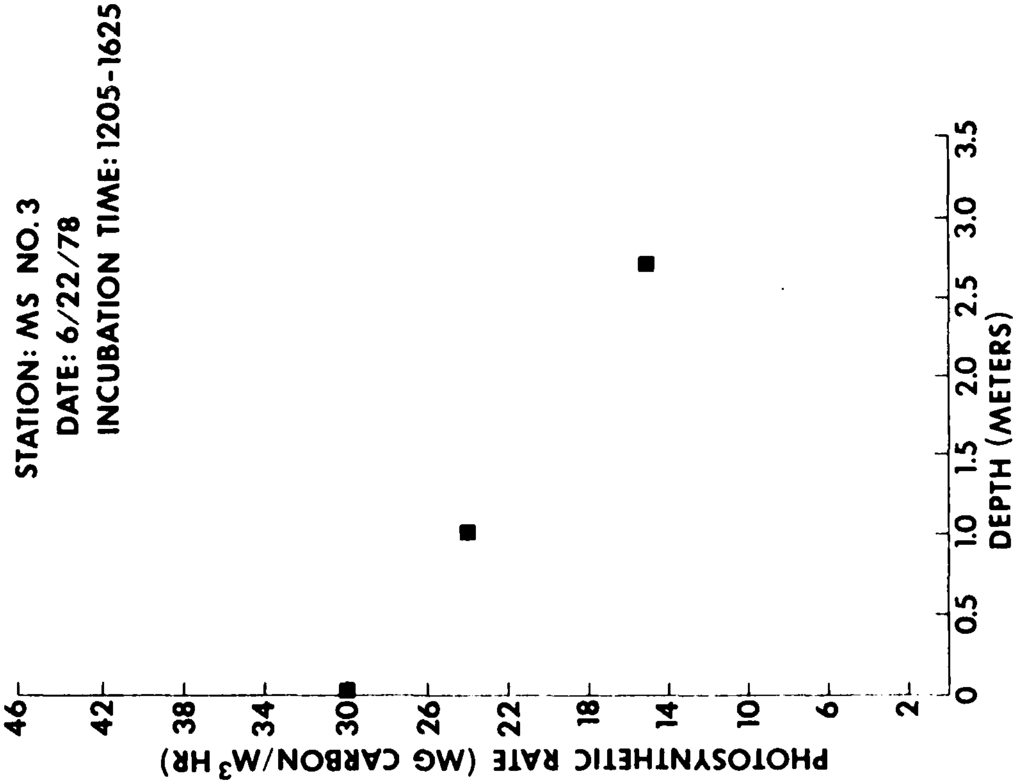
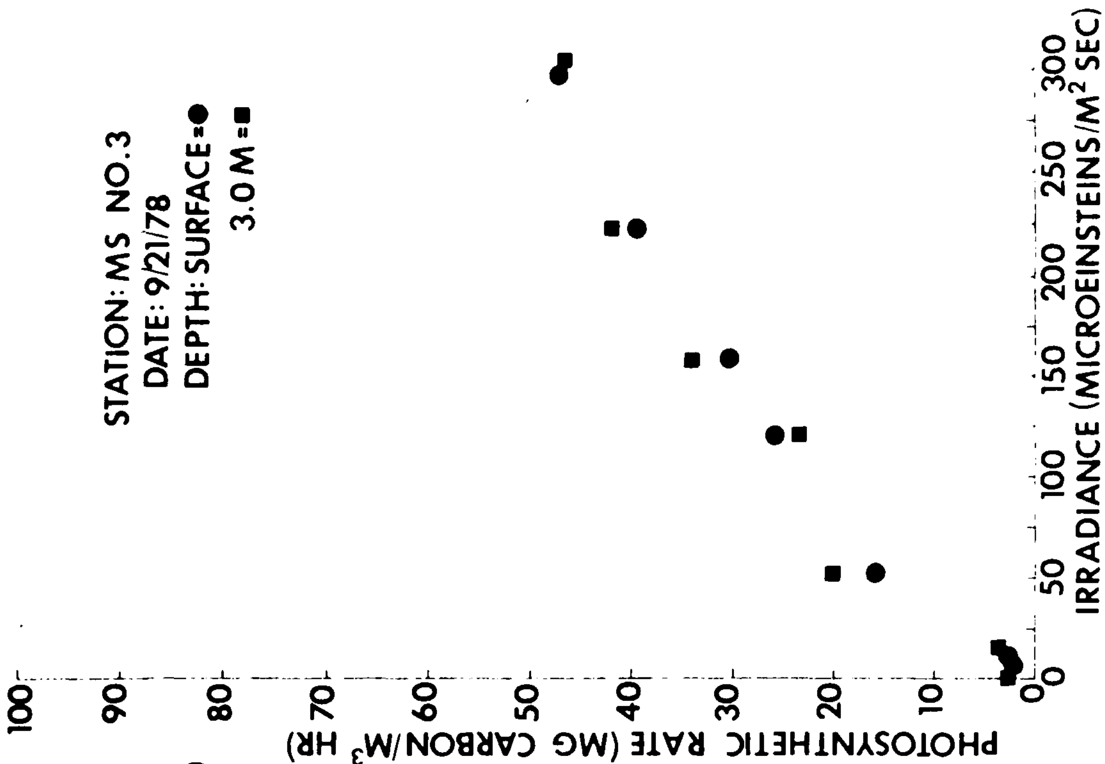
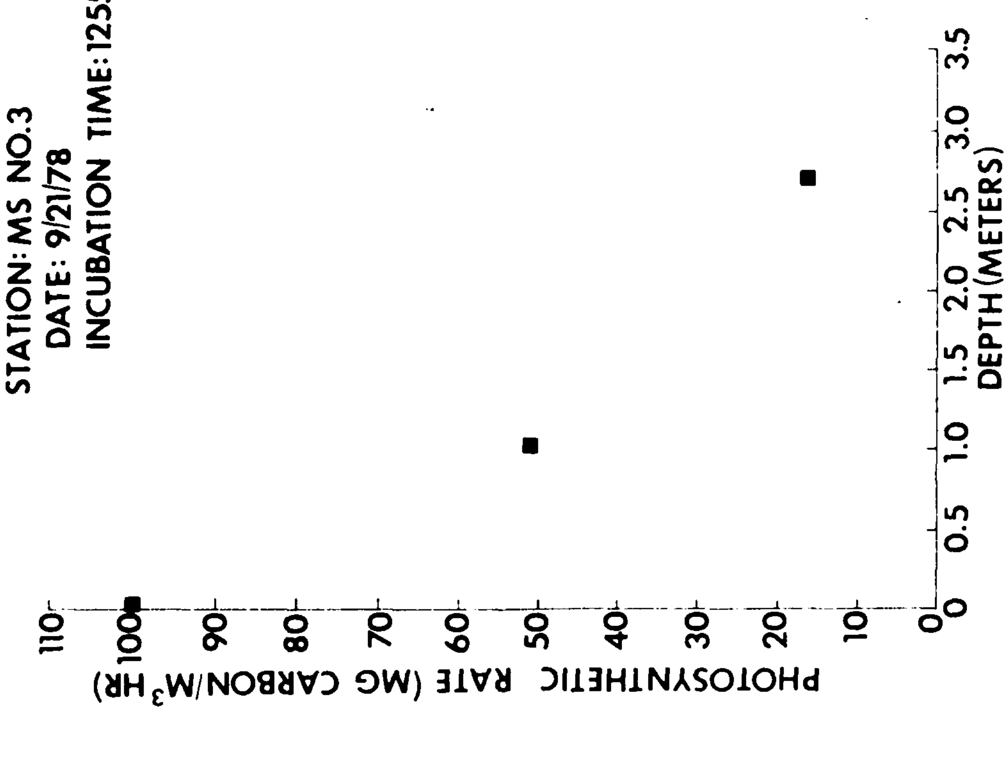
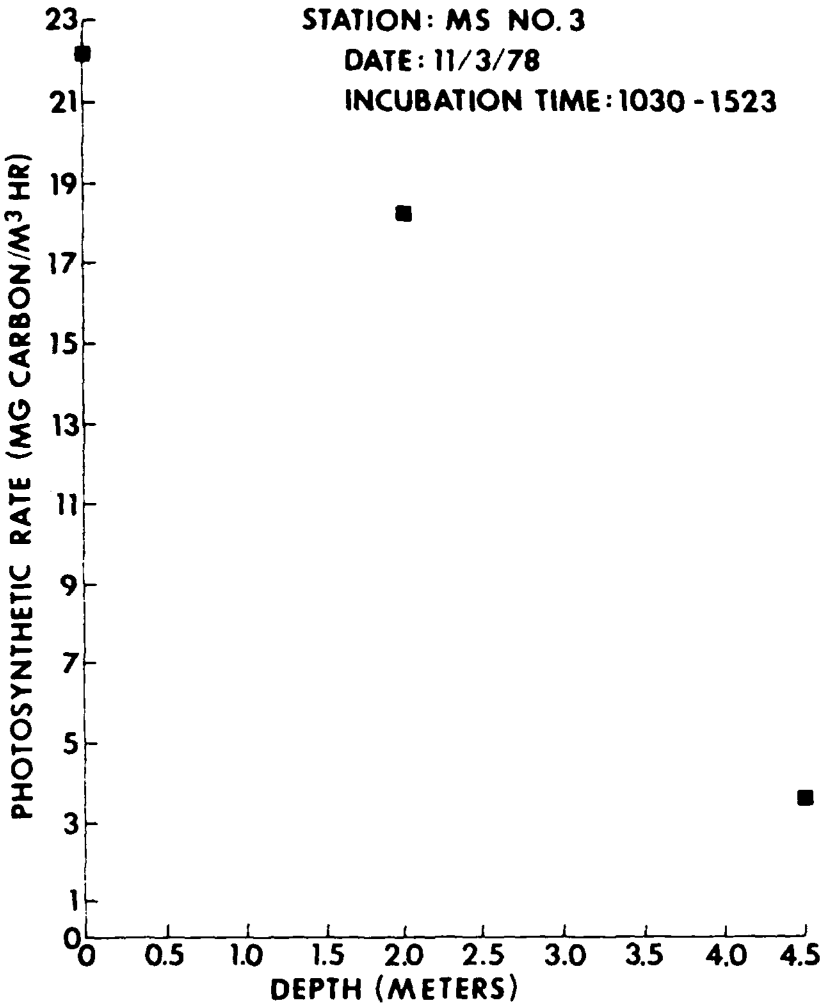
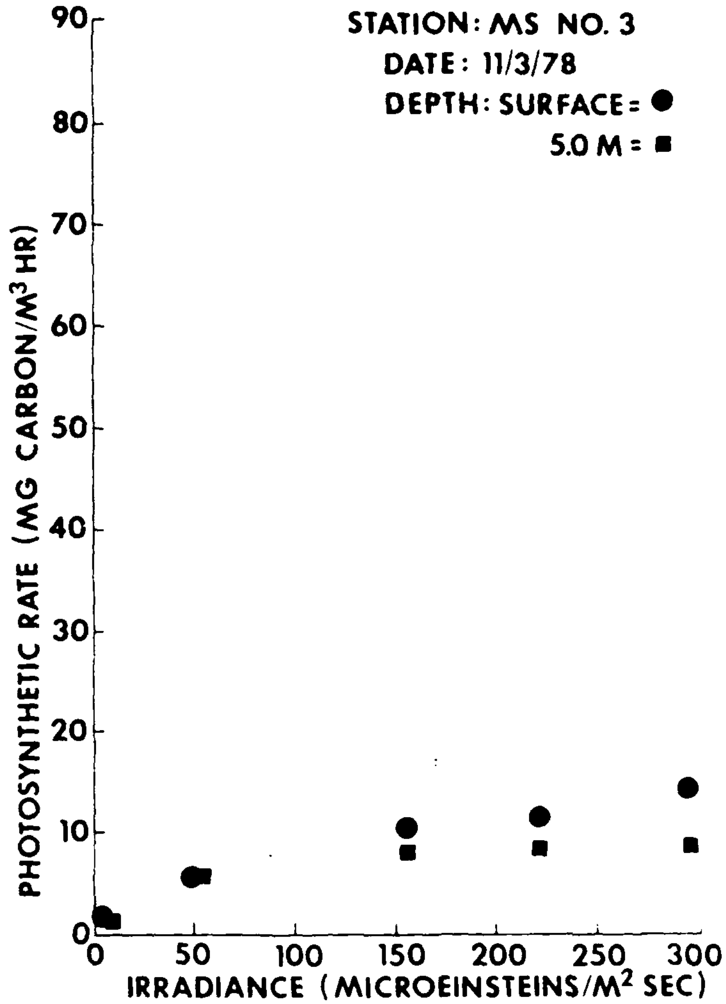
DATE: 6/22/78
DEPTH: SURFACE=
3.0 M=
PHOTOSYNTHETIC RATE (MG CARBON/M^3 HR)
IRRADIANCE (MICROEINSTEINS/M^2 SEC)
0
10
20
30
40
50
60
70
80
90
50
100
150
200
250
300

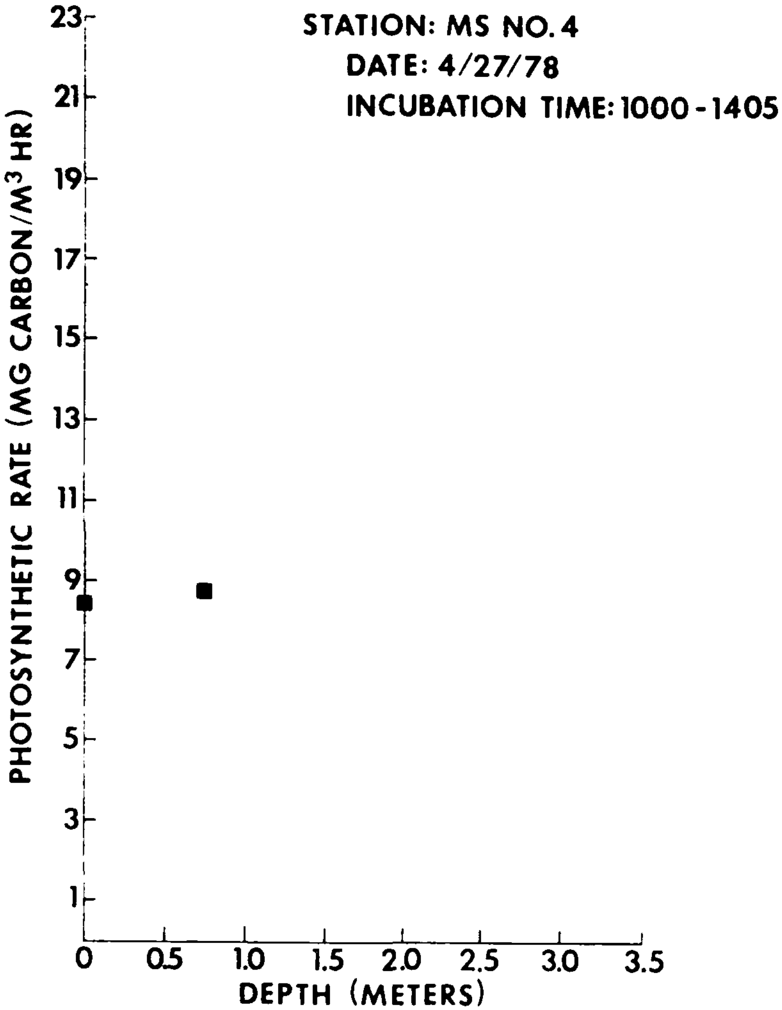

STATION: MS NO. 3
DATE: 6/22/78
INCUBATION TIME: 1205-1625
PHOTOSYNTHETIC RATE (MG CARBON/M^3 HR)
DEPTH (METERS)
2
6
10
14
18
22
26
30
34
38
42
46
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5


STATION: MS NO.3
DATE: 9/21/78
DEPTH: SURFACE = ●
3.0 M = ■
PHOTOSYNTHETIC RATE (MG CARBON/M³ HR)
0
10
20
30
40
50
60
70
80
90
100
IRRADIANCE (MICROEINSTEINS/M² SEC)
0
50
100
150
200
250
300

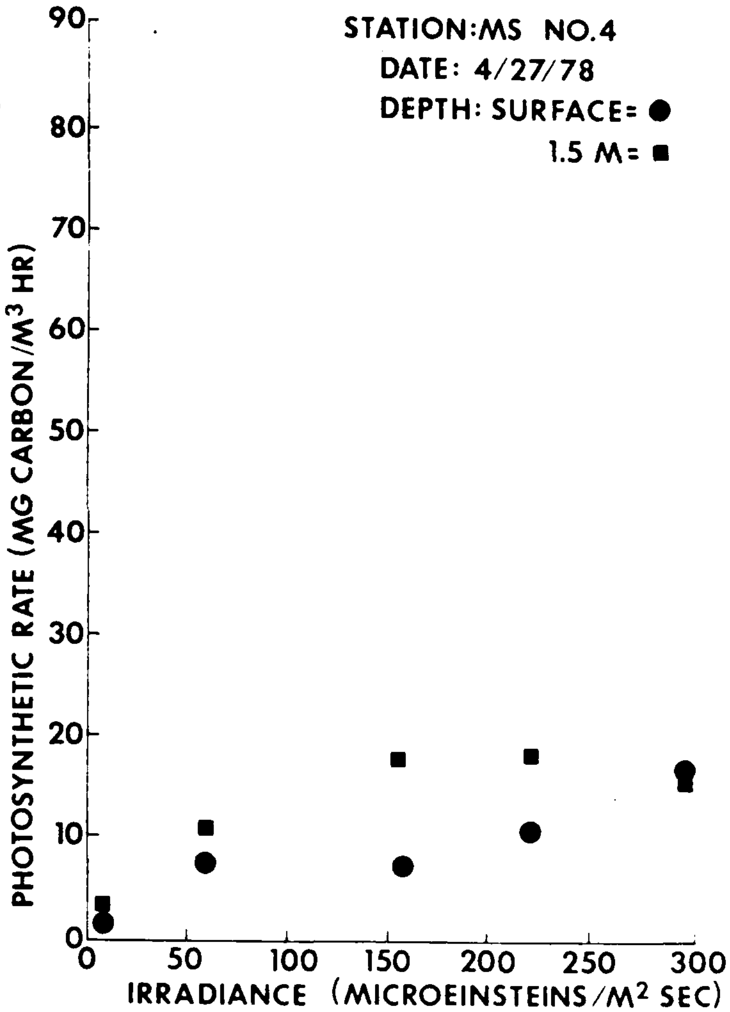

STATION: MS NO.3
DATE: 9/21/78
INCUBATION TIME: 1255-1710
PHOTOSYNTHETIC RATE (MG CARBON/M³ HR)
0
10
20
30
40
50
60
70
80
90
100
110
DEPTH (METERS)
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5


STATION: MS NO. 3
DATE: 11/3/78
INCUBATION TIME: 1030 - 1523
PHOTOSYNTHETIC RATE (MG CARBON/M3 HR)
23
21
19
17
15
13
11
9
7
5
3
1
0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
DEPTH (METERS)

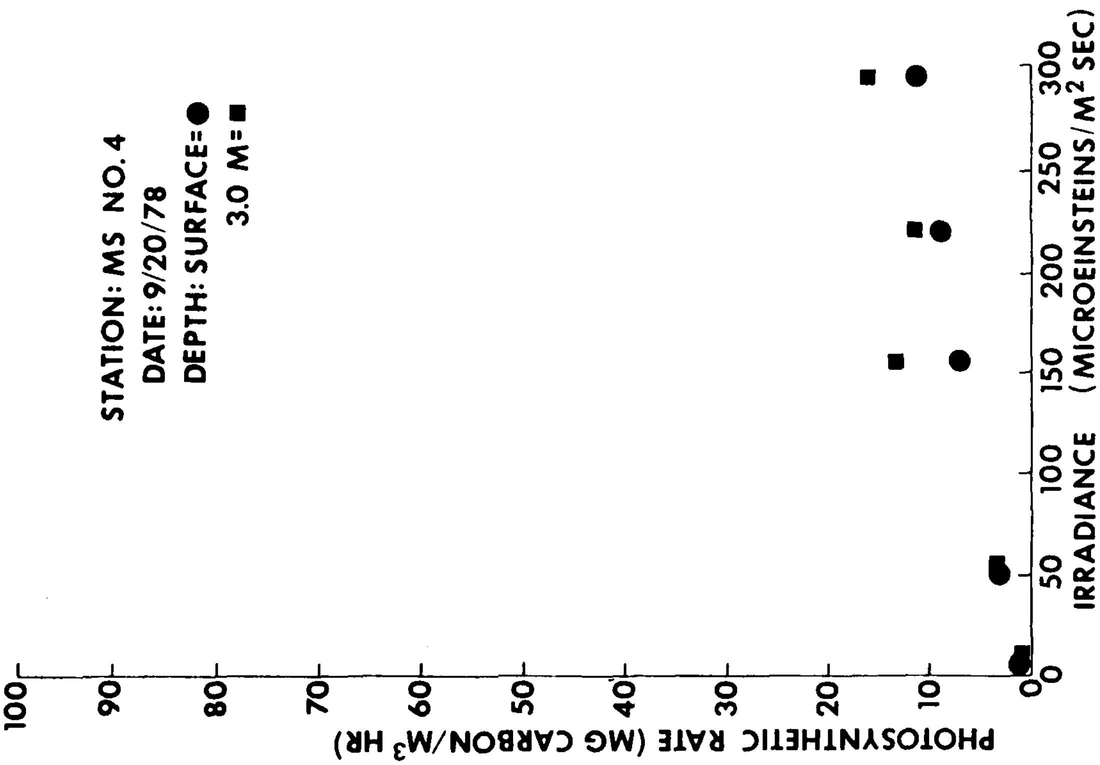

STATION: MS NO. 3
DATE: 11/3/78
DEPTH: SURFACE = ●
5.0 M = ■
PHOTOSYNTHETIC RATE (MG CARBON/M3 HR)
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
IRRADIANCE (MICROEINSTEINS/M2 SEC)

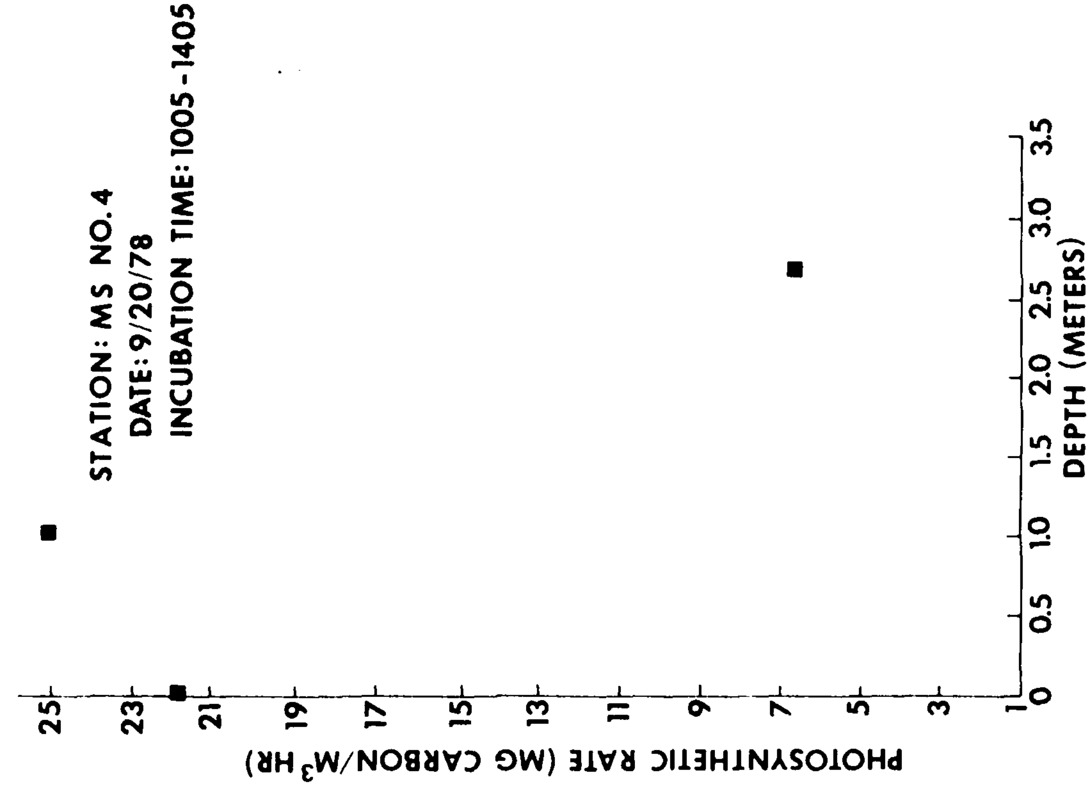


STATION: MS NO. 4
DATE: 4/27/78
INCUBATION TIME: 1000 - 1405
PHOTOSYNTHETIC RATE (MG CARBON/M³ HR)
DEPTH (METERS)



STATION: MS NO. 4
DATE: 4/27/78
DEPTH: SURFACE= ●
1.5 M= ■
PHOTOSYNTHETIC RATE (MG CARBON/M³ HR)
IRRADIANCE (MICROEINSTEINS/M² SEC)

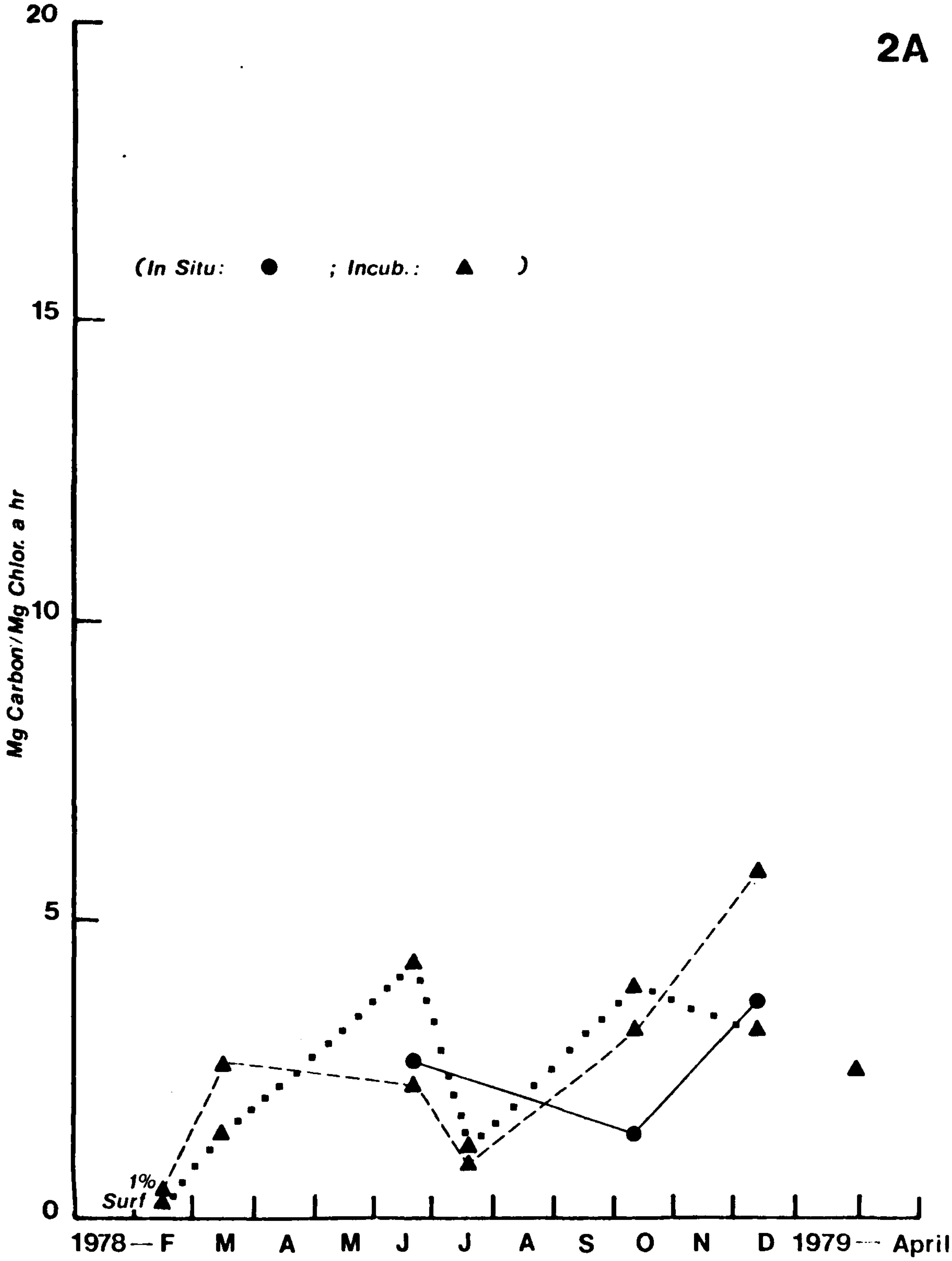

STATION: MS NO. 4
DATE: 9/20/78
DEPTH: SURFACE=●
3.0 M=■
PHOTOSYNTHETIC RATE (MG CARBON/M3 HR)
IRRADIANCE (MICROEINSTEINS/M2 SEC)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300

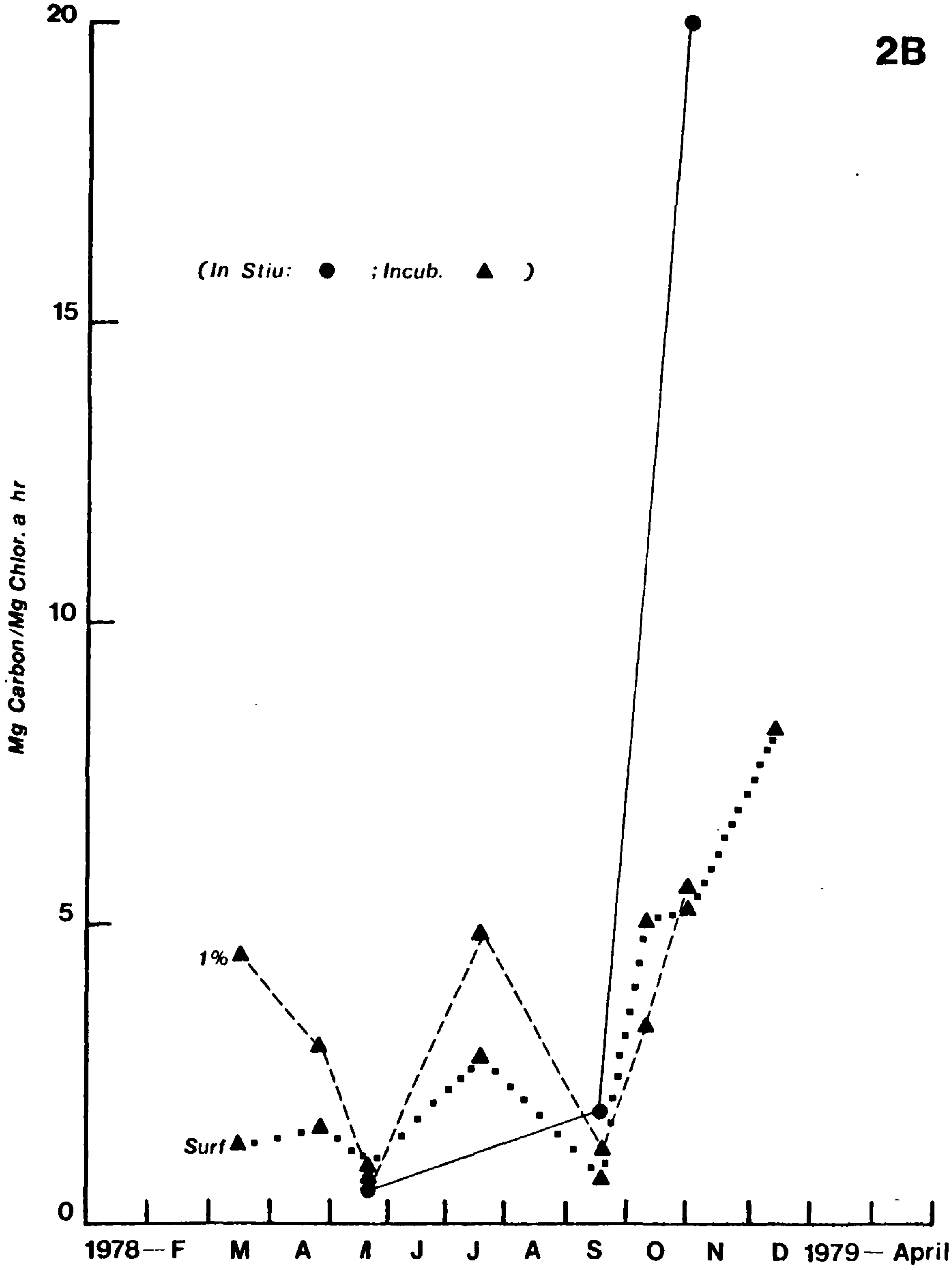

STATION: MS NO. 4
DATE: 9/20/78
INCUBATION TIME: 1005-1405
PHOTOSYNTHETIC RATE (MG CARBON/M3 HR)
DEPTH (METERS)
1
3
5
7
9
11
13
15
17
19
21
23
25
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

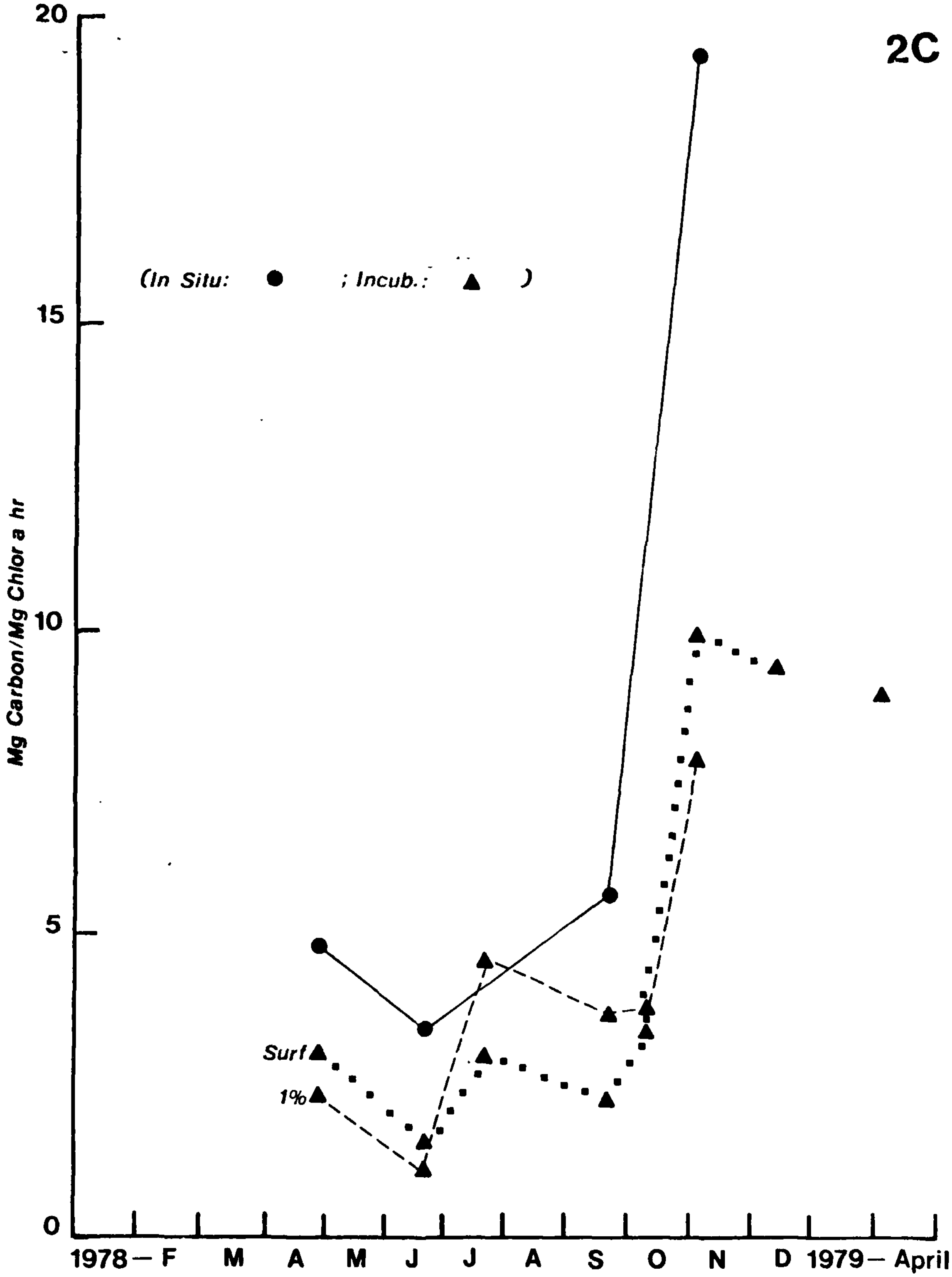
APPENDIX 2

Assimilation Ratios

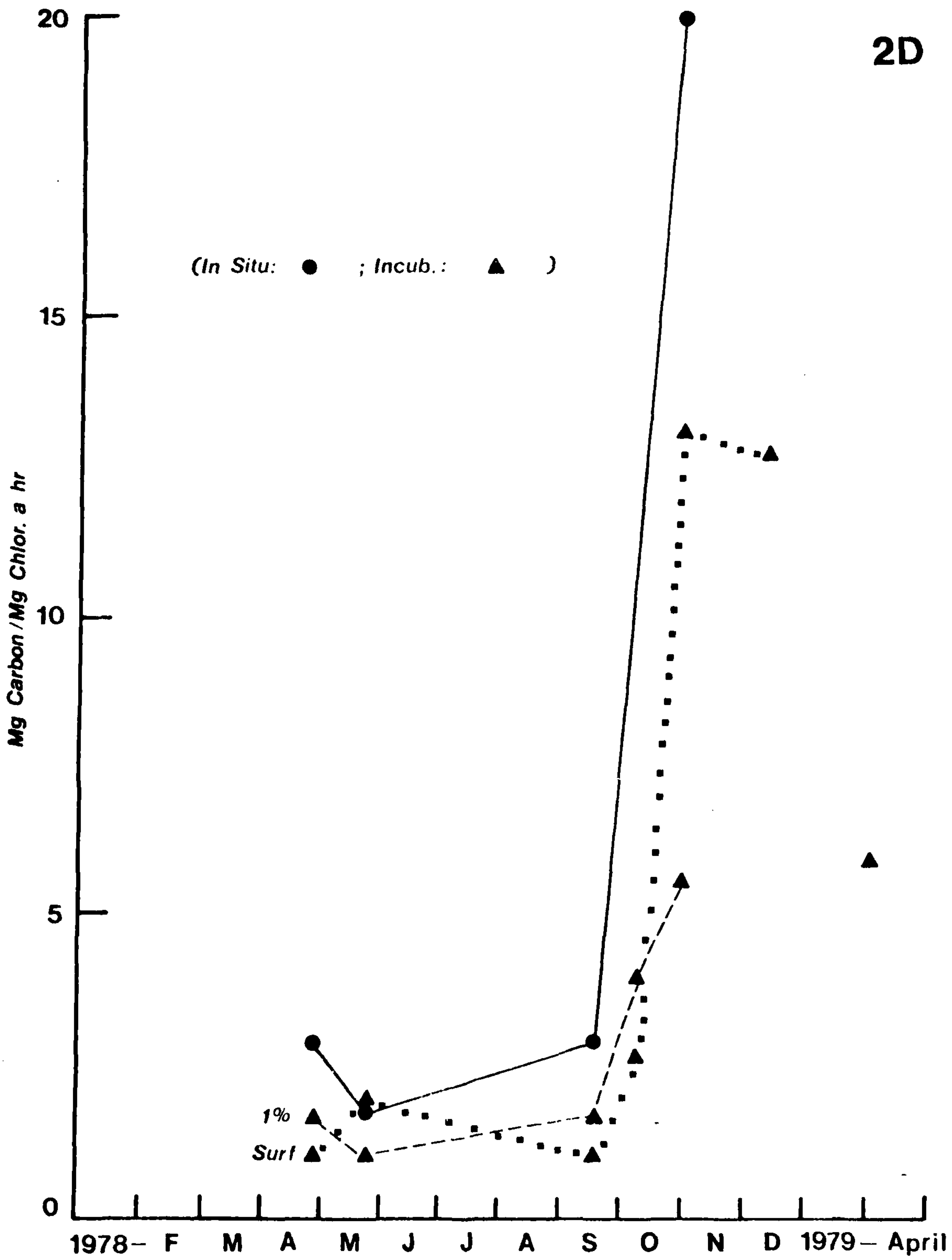
The monthly changes in assimilation ratios at each of the four master stations. The *in situ* incubations are for samples from the surface water and incubated there. The samples placed in the incubator were collected at either the surface or where the 1% light intensity depth and incubated at 73% of the maximum light intensity. A=MS1; B=MS2; C=MS3; D=MS4.


2A
(In Situ: ● ; Incub.: ▲)
Mg Carbon / Mg Chlor. a hr
20
15
10
5
0
1%
Surf
1978 — F M A M J J A S O N D 1979 — April


2B
(In Stiu: ● ; Incub. ▲)
Mg Carbon/Mg Chlor. a hr
20
15
10
5
0
1%
Surf
1978— F
M
A
M
J
J
A
S
O
N
D
1979— April



2C
(In Situ: ● ; Incub.: ▲)
Mg Carbon/Mg Chlor a hr
20
15
10
5
0
Surf
1%
1978 — F
M
A
M
J
J
A
S
O
N
D
1979 — April



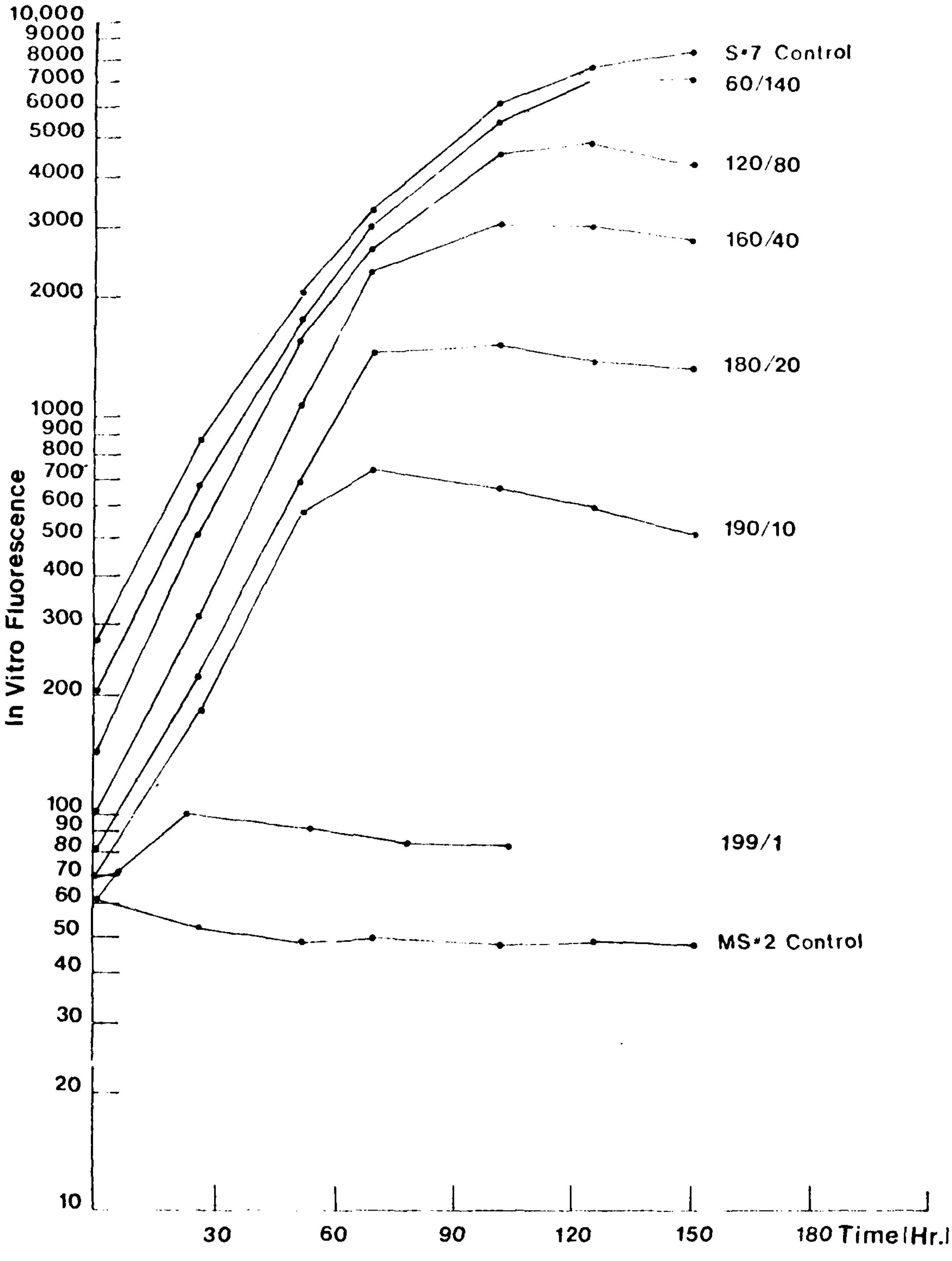
20
15
10
5
0
2D
(In Situ: ● ; Incub.: ▲)
Mg Carbon/Mg Chlor. a hr
1%
Surf
1978– F M A M J J A S O N D 1979– April

APPENDIX 3

Transfer Study

Results of the transfer study. The experiment was conducted as described in the text. Organisms from one station were mixed with various dilutions of the source water and from another station. The purpose was to discover if the results of mixing plankton with a different water mass (as occurs at the tidal passes, for example) would have a stimulatory or inhibitory effect on the source plankton. 3A was conducted November 22, 1978 and involved stations S7 and MS2. 3B was conducted December 2, 1978 and involved stations S3 and E8. In Table 3C and 3D are the chemical and biological data for a transfer study in May and June, respectively.

3A



10,000
9000
8000
7000
6000
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
In Vitro Fluorescence
S•7 Control
60/140
120/80
160/40
180/20
190/10
199/1
MS•2 Control
30
60
90
120
150
180
Time (Hr.)

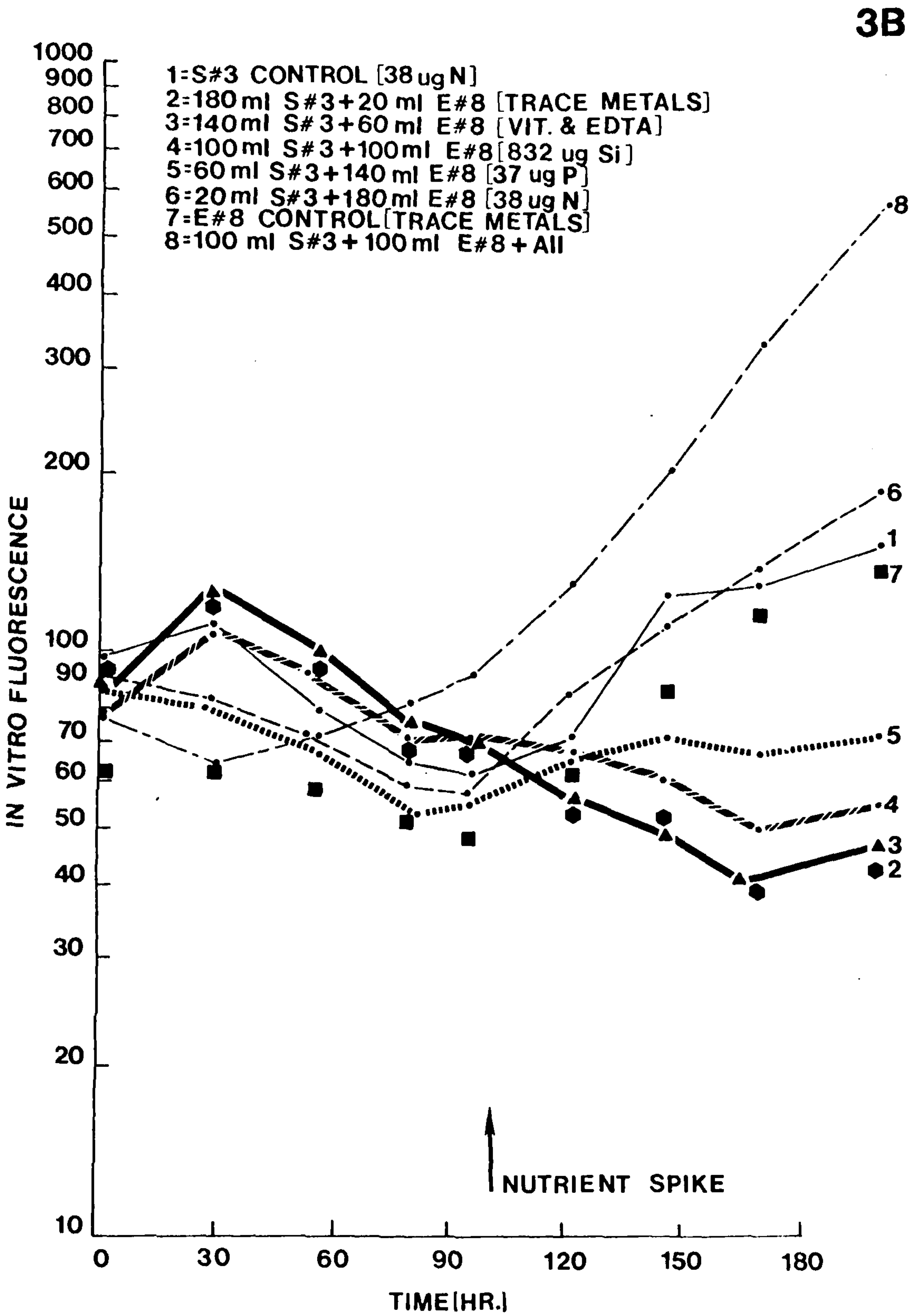

3B
1=S#3 CONTROL [38 ug N]
2=180 ml S#3+20 ml E#8 [TRACE METALS]
3=140 ml S#3+60 ml E#8 [VIT. & EDTA]
4=100 ml S#3+100 ml E#8 [832 ug Si]
5=60 ml S#3+140 ml E#8 [37 ug P]
6=20 ml S#3+180 ml E#8 [38 ug N]
7=E#8 CONTROL [TRACE METALS]
8=100 ml S#3+100 ml E#8+All
IN VITRO FLUORESCENCE
NUTRIENT SPIKE
TIME (HR.)

Table 3C

Transfer Study on May 26, 1978, between Lake Borgne and The Rigolets

Bottle #1: Rigolets Organisms in Rigolets Water
Bottle #2: Lake Borgne Organisms in Rigolets Water
Bottle #3: Lake Borgne Organisms in Lake Borgne Water
Bottle #4: Rigolets Organisms in Lake Borgne Water

Bottle & Time	Total Dis. Phosphorus (ppb)	PO_4 (ppb)	NH_4 (ppb)	NO_2 & NO_3 (ppb)	Dissolved Org. Nitrogen (ppb)
#1- 0 hr.	22.8	13.9	0	22.5	598
#1- 1 hr.	4.0	0	10	14.6	334
#1- 2 hr.	9.1	4.8	0	0	575
#1- 4 hr.	8.6	3.8	0	207	477
#1- 6 hr.	18.3	13.7	0	98.2	770
#2- 0 hr.	11.3	0	8	51.4	1117
#2- 1 hr.	21.3	7.8	0	31.7	290
#2- 2 hr.	9.8	0	8	25.8	380
#2- 4 hr.	5.1	4.5	0	98.2	450
#2- 6 hr.	2.5	2.2	7	119	402
#3- 0 hr.	31.5	19.6	24	11.8	520
#3- 1 hr.	7.2	0	0	51.3	691
#3- 2 hr.	15.2	3.1	0	124	611
#3- 4 hr.	6.3	1.6	0	82.7	437
#3- 6 hr.	2.3	2.7	0	124	780
#4- 0 hr.	20.8	13.5	6	30.9	355
#4- 1 hr.	9.1	3.9	0	23.6	468
#4- 2 hr.	22	21.3	3	41.4	1021
#4- 4 hr.	3.9	0.5	0	176	531
#4- 6 hr.	0.7	0.2	0	119	504

Table 3C. (Continued)

Transfer Study on May 26, 1978, Between Lake Borgne and The Rigolets

Bottle & Time	SiO_2 (ppb)	Inorganic Carbon (ppb)	Chlorophyll a (ppb)	Phaeophytin (ppb)	C14 Part. (ppb)	Production Dissol (ppb)	Assimilation Ration
#1- 0 hr.	3060	9320	7.0	2.6			
#1- 1 hr.	2340		11.7	10.1	113.2	8.4	9.7
#1- 2 hr.	2030		11.7	10.1	106.8	6.7	9.1
#1- 4 hr.	3030		10.2	8.4	95.1	5.3	9.4
#1- 6 hr.	3520	5020	11.2	8.0	72.0	6.0	6.4
#2- 0 hr.	2670	5210	9.8	6.8			
#2- 1 hr.	3010		6.9	7.8	53.2	5.1	7.7
#2- 2 hr.	2960		6.0	6.4	49.1	4.0	8.1
#2- 4 hr.	3220		6.9	5.6	52.7	2.8	7.6
#2- 6 hr.	3670	5330	7.5	4.2	53.2	4.8	7.1

Table 3C. (Continued)

Transfer Study on May 26, 1978, Between Lake Borgne and The Rigolets

Bottle & Time	SiO_2 (ppb)	Inorganic Carbon (ppb)	Chlorophyll a (ppb)	Phaeophytin (ppb)	C14 Part. (ppb)	Production Dissol (ppb)	Assimilation Ration
#3- 0 hr.	3580	4170	6.4	4.6			
#3- 1 hr.	3480		7.4	5.4	68.2	12.2	9.2
#3- 2 hr.	3690		6.6	1.7	55.8	5.0	8.4
#3- 4 hr.	3090		6.9	3.3	37.5	4.5	5.4
#3- 6 hr.	2560	4050	7.8	6.9	39.4	3.6	5.0
#4- 0 hr.	2870	4780	9.4	7.5			
#4- 1 hr.	2490		12.6	11.5	108.5	8.6	8.6
#4- 2 hr.	4370		12.0	8.3	76.8	6.2	6.4
#4- 4 hr.	3010		13.9	9.3	54.2	3.9	3.9
#4- 6 hr.	3370	4500	13.7	9.9	52.3	4.4	3.8

Table 3D

June Transfer Study: Lake Maurepas-Pass Manchac Nutrient Chemistry Data

Bottle No. and sample time	NH_4 (ppb)	$NO_2 + NO_3$ (ppb)	Diss. Org. N (ppb)	PO_4 (ppb)	Total Diss. P (ppb)	SiO_2 (ppb)	Conduct. (umhos/cm)
Bottle #1							
0	75	14	417	29	27	312	2220
1	1	57	534	2	23	5430	2240
2	35	40	402	16	17	678	2310
4	83	29	459	22	11	398	2680
6	38	--	371	19	18	312	2380
Bottle #2							
0	45	43	336	18	18	1090	1660
1	41	37	463	18	18	894	2090
2	85	37	465	27	27	778	2250
4	39	6	595	14	14	416	2540
6	29	8	420	8	8	642	2590

Table 3D. (Continued)

June Transfer Study: Lake Maurepas-Pass Manchac Nutrient Chemistry Data - (Continued)

Bottle No. and sample time	NH_4 (ppb)	$NO_2 + NO_3$ (ppb)	Diss. Org. N (ppb)	PO_4 (ppb)	Total Diss. P (ppb)	SiO_2 (ppb)	Conduct. (umhos/cm)
Bottle #3							
0	4	41	599	52	52	496	1020
1	4	30	635	14	14	546	971
2	67	39	550	56	56	868	1050
4	92	11	626	32	32	695	1190
6	32	24		30	30	503	1120
Bottle #4							
0	66	31	482	32	32	1350	1160
1	6	48	538	16	16	698	1120
2	73	43	492	54	54	513	1160
4	62	--	523	6	6	1820	1420
6	40	1	461	6	6	430	1430

Table 3D

June Transfer Study: Lake Maurepas-Pass Manchac

Location-time (hr)	Chlor. a ug/1	Phaeophy. ug/1	pH	^{14}C productivity ($mg.m^{-3}.hr^{-1}$) Light	Dark	Dissolved	Assim. ratio
Bottle #1							
0	2.9	2.4	7.88				
1	---	---	7.89	28.40	4.50	79.50	9.8
2	3.1	0.6	8.05	24.84	1.28	22.79	7.4
4	2.8	2.4	8.02	19.29	0.75	18.74	6.8
6	3.2	0.6	8.09	15.10	0.88	10.73	4.8
Bottle #2							
0	20.5	5.7	8.28				
1	---	---	8.46	214.46	17.96	67.34	10.5
2	20.6	4.6	8.56	183.54	11.05	34.55	8.9
4	19.0	6.3	8.82	166.20	6.55	14.29	8.8
6	17.4	5.8	8.93	152.86	3.31	15.68	8.8
Bottle #3							
0	19.2	4.5	9.45				
1	18.9	3.0	9.47	210.53	13.02	52.0	11.1
2	20.6	6.9	9.45	213.69	13.01	21.1	9.8
4	20.0	1.4	9.58	175.95	7.94	18.86	8.8
6	17.6	0.6	9.60	129.8	1.68	17.06	7.4

Table 3D. (Continued)

June Transfer Study: Lake Maurepas-Pass Manchac

Location-time (hr)	Chlor. a ug/l	Phaeophy. ug/l	pH	^{14}C productivity ($mg.m^{-3}.hr^{-1}$) Light	Dark	Dissolved	Assim. ratio
Bottle #4							
0	2.8	0.4	9.22				
1	2.6	3.1	9.17	21.82	1.23	38.23	8.6
2	2.6	3.1	9.04	23.12	0.82	8.49	9.1
4	2.6	1.9	9.08	20.46	0.61	9.55	8.0
6	2.3	2.6	9.03	17.66	3.79	3.34	7.7

Bottle #1: Pass Manchac Water + Pass Manchac Organisms.

Bottle #2: Pass Manchac Water + Lake Maurepas Organisms.

Bottle #3: Lake Maurepas Water + Lake Maurepas Organisms.

Bottle #4: Lake Maurepas Water + Pass Manchac Organisms.

APPENDIX 4

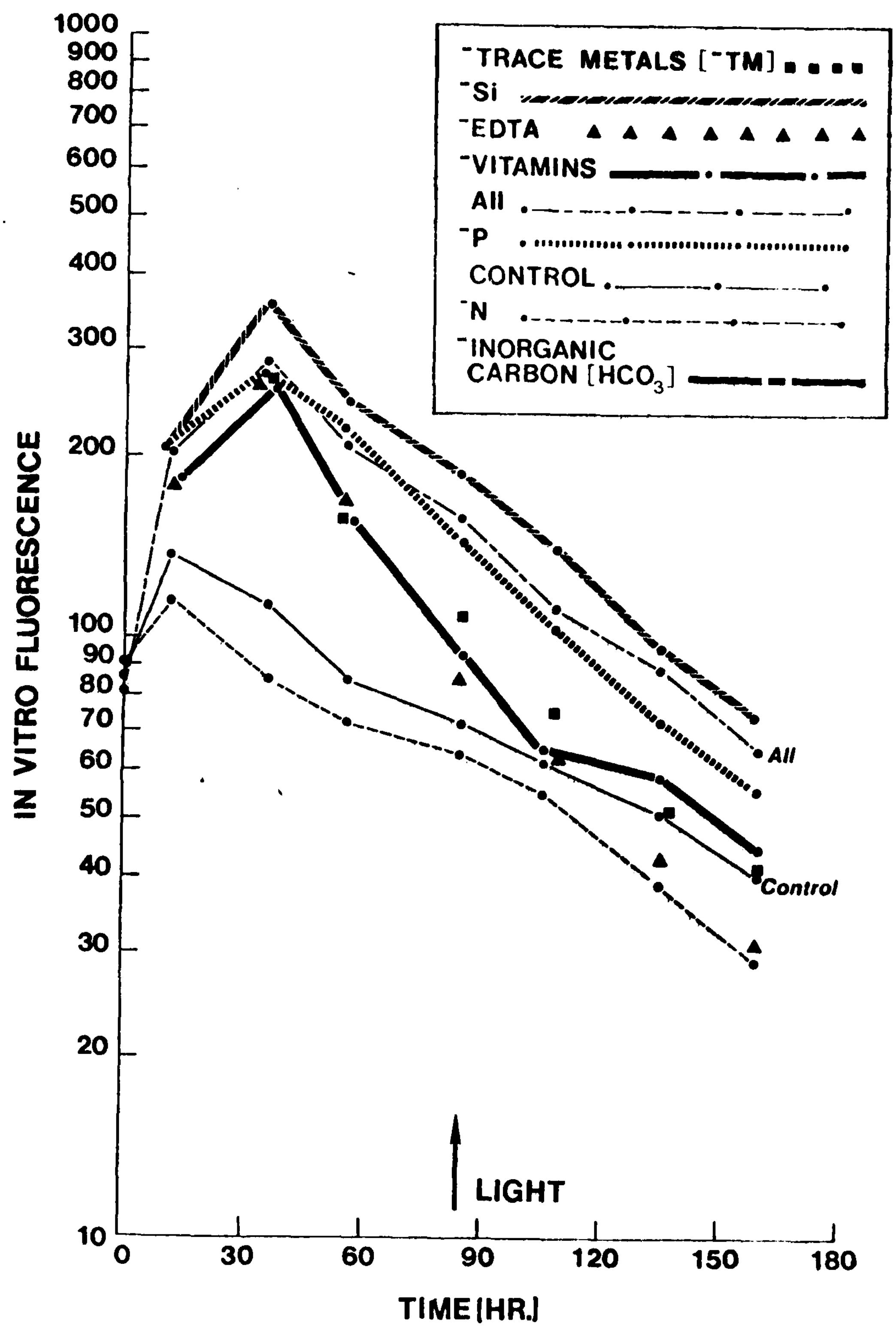
Bioassay Results

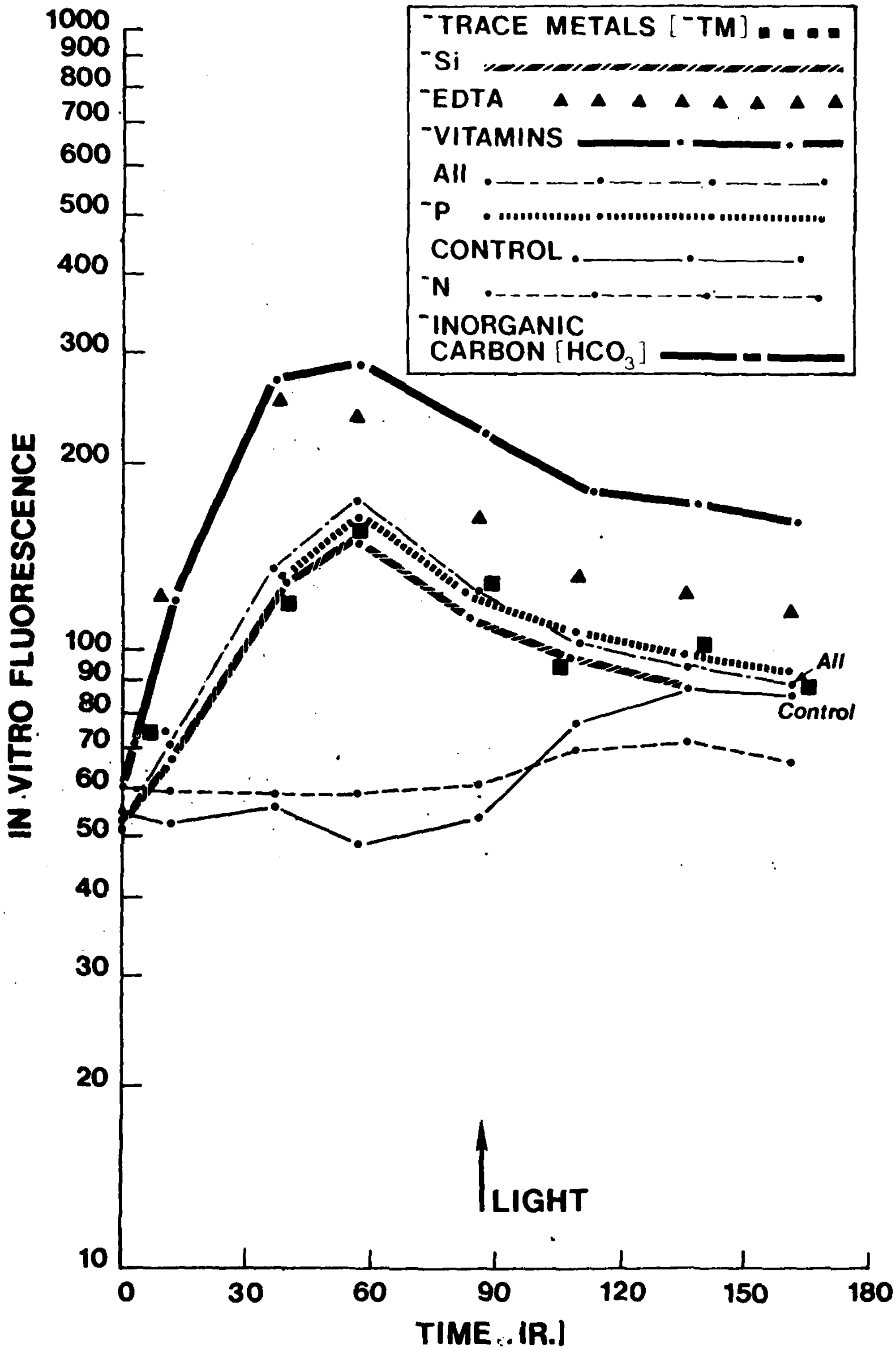
Bioassays were conducted as described in the text. The growth of an innoculum of plankton from the station indicated were incubated in a bioassay medium. The medium had all of numerous chemical components except one, which is indicated. The vertical axis is in relative fluorescence units (measured in a fluorometer) and the horizontal axis is time (hours) from the beginning of the experiment. In all cases the bioassay without nitrogen was as inactive as the control solution; the latter was usually lower.

4A - December 17, 1978; Station MS4
4B - November

Appendix	Sampling Date (1978)	Station
A-4A	November 11	MS4
A-4B	"	E4
A-4C	November 21	MS2
A-4D	"	E14
A-4E	"	MS3
A-4F	December 3	S3
A-4G	"	MS1
A-4H	December 5	E8
A-4I	December 17	S5
A-4J	"	MS4

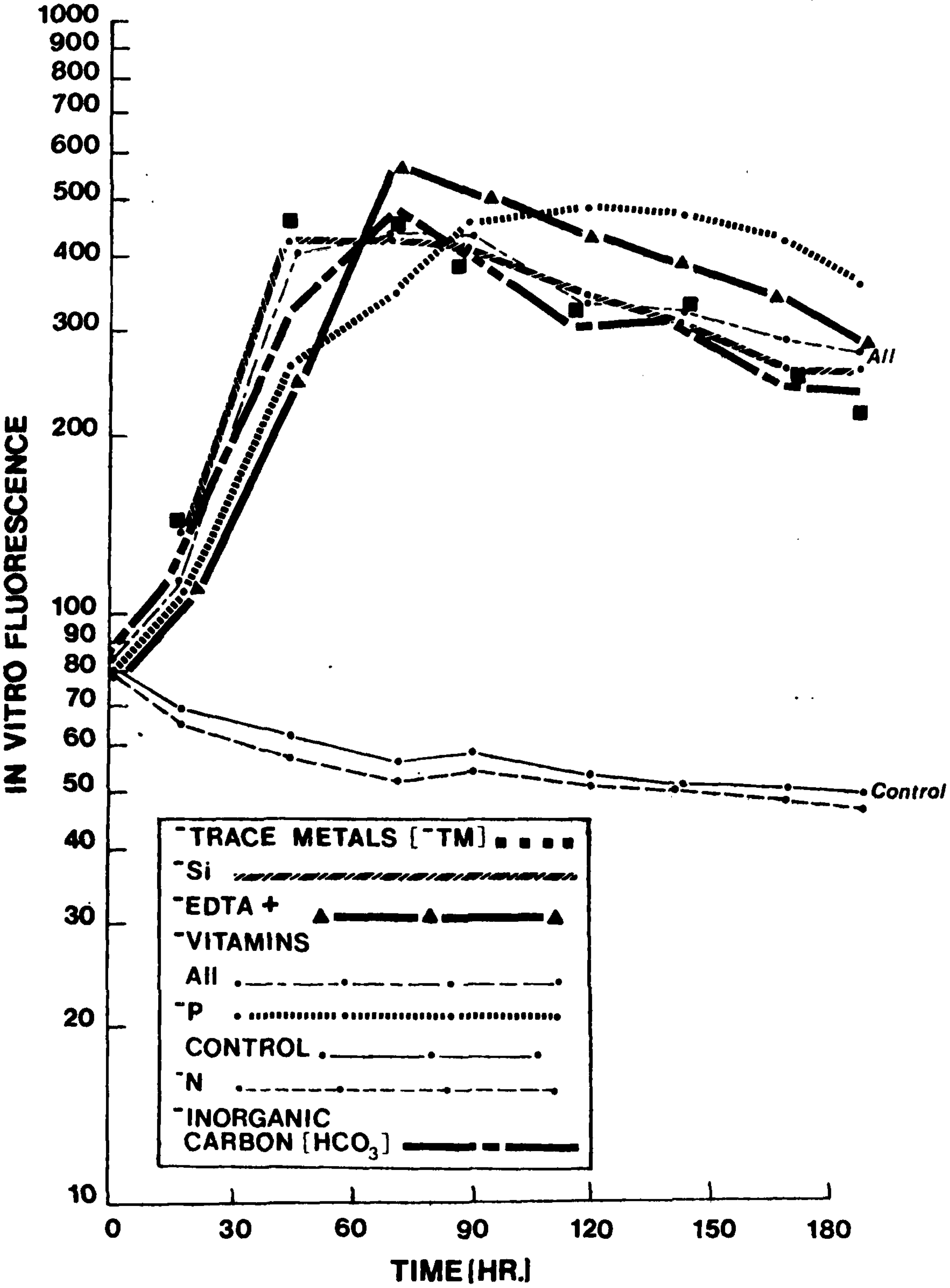
4A


IN VITRO FLUORESCENCE
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
0
30
60
90
120
150
180
TIME (HR.)
LIGHT
All
Control
⁻TRACE METALS [⁻TM]
⁻Si
⁻EDTA
⁻VITAMINS
All
⁻P
CONTROL
⁻N
⁻INORGANIC CARBON [HCO_3]

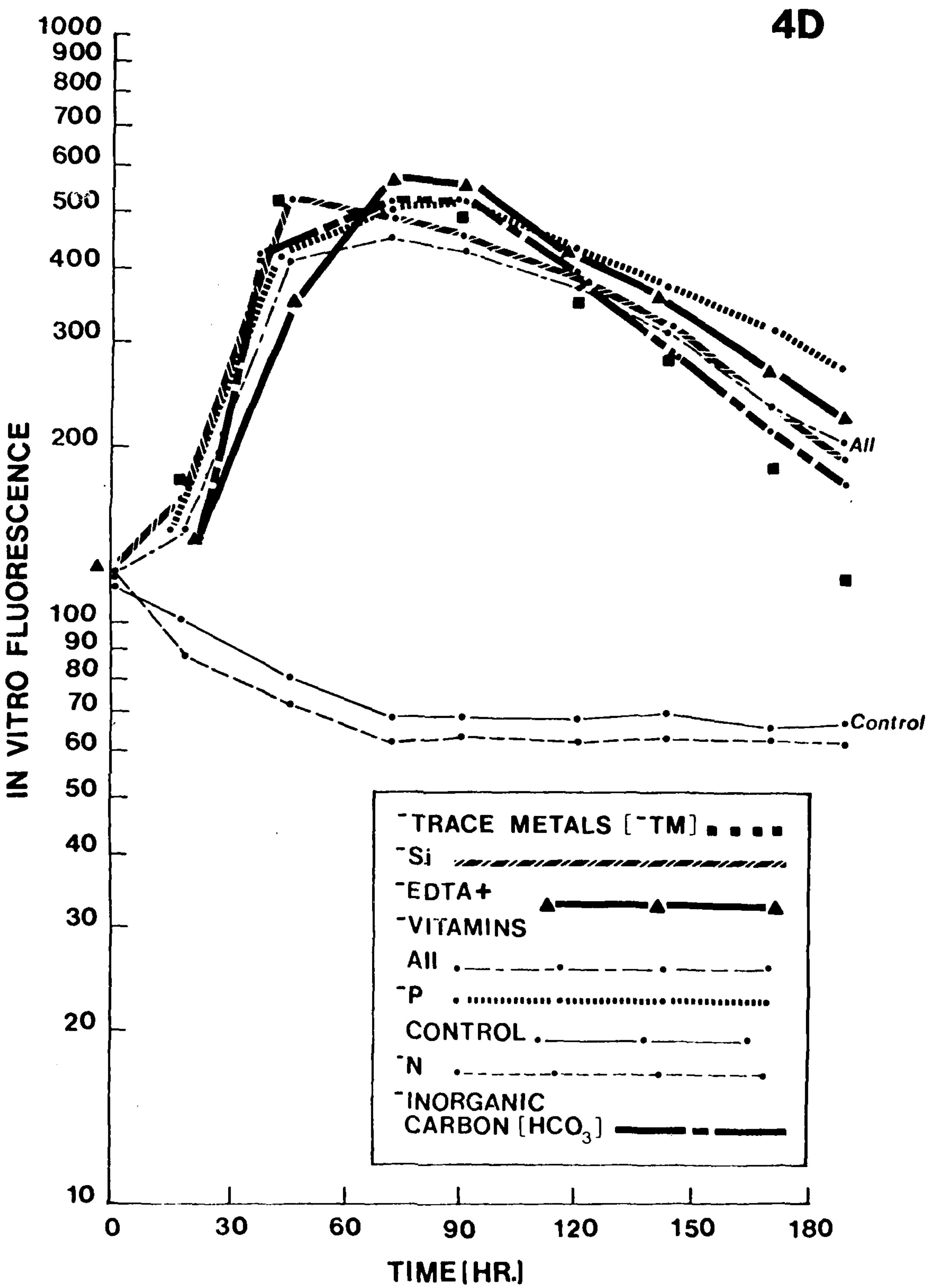


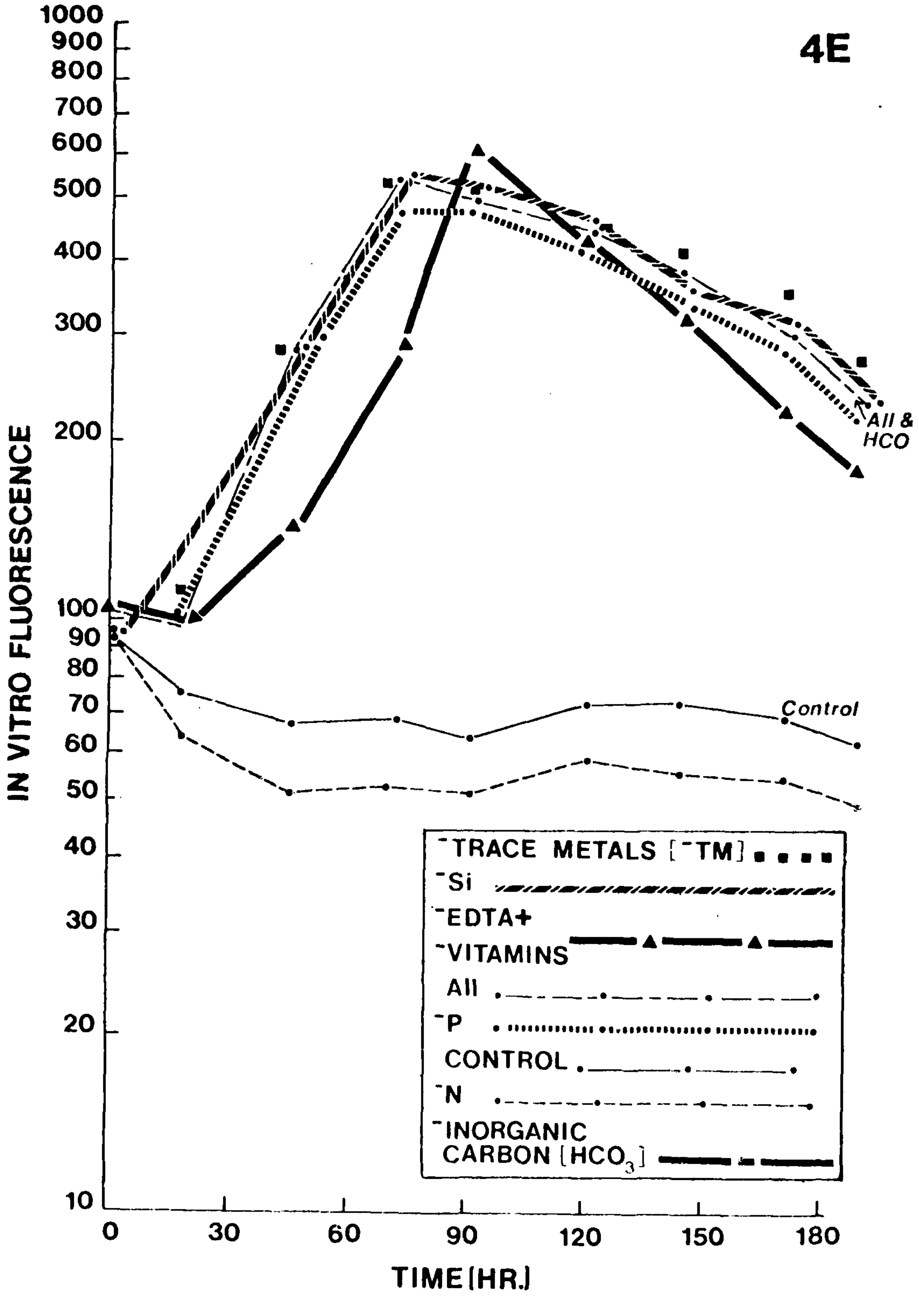
‾TRACE METALS [‾TM]
‾Si
‾EDTA
‾VITAMINS
All
‾P
CONTROL
‾N
‾INORGANIC CARBON [HCO_3]
IN VITRO FLUORESCENCE
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
All
Control
LIGHT
0
30
60
90
120
150
180
TIME . IR.]

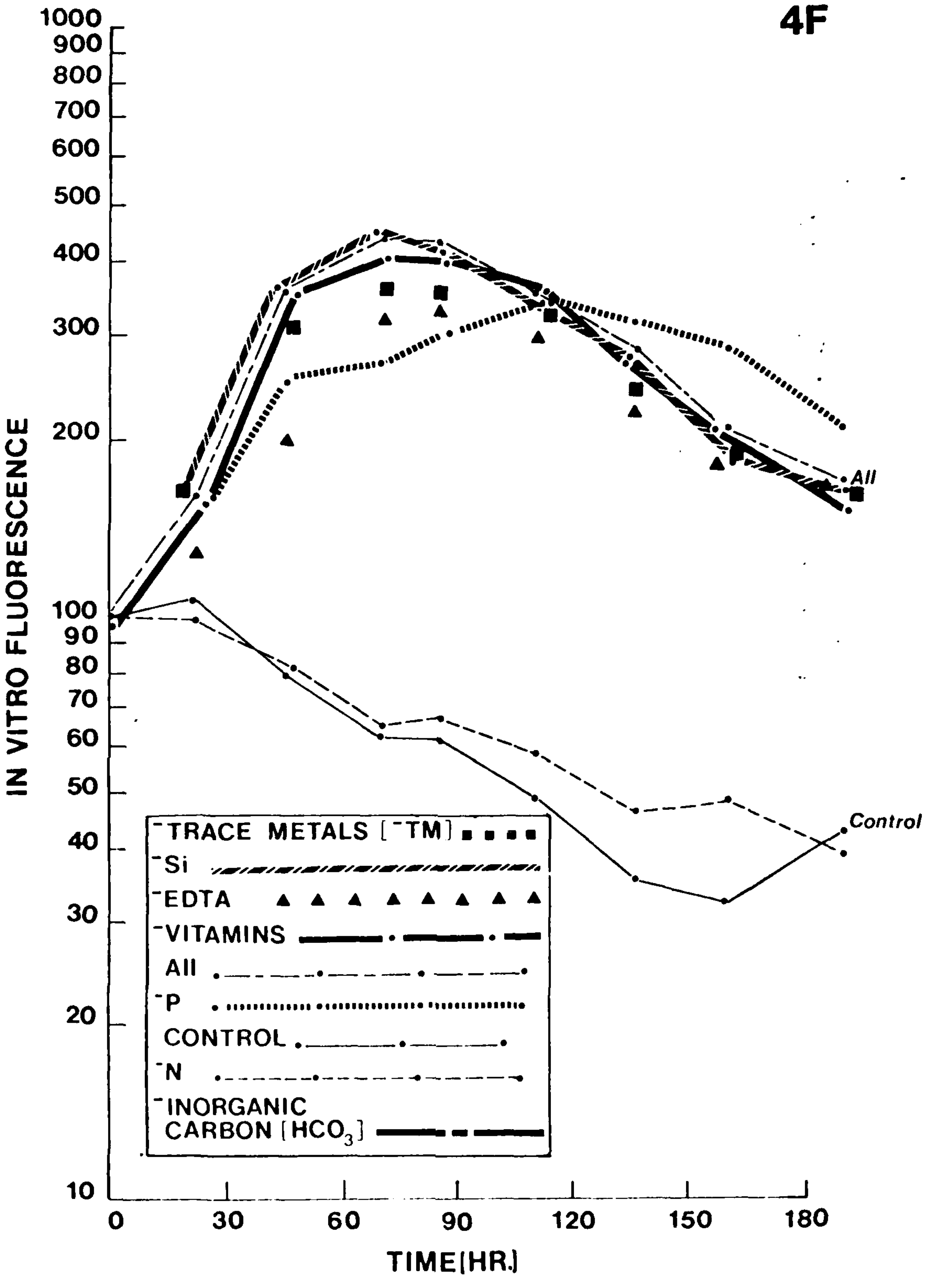
4C



IN VITRO FLUORESCENCE
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
0
30
60
90
120
150
180
TIME (HR.)
All
Control
⁻TRACE METALS [⁻TM]
⁻Si
⁻EDTA +
⁻VITAMINS
All
⁻P
CONTROL
⁻N
⁻INORGANIC
CARBON [HCO3]


4D
IN VITRO FLUORESCENCE
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
0
30
60
90
120
150
180
TIME (HR.)
All
Control
⁻TRACE METALS [⁻TM]
⁻Si
⁻EDTA+
⁻VITAMINS
All
⁻P
CONTROL
⁻N
⁻INORGANIC
CARBON [HCO_3]


4E
IN VITRO FLUORESCENCE
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
0
30
60
90
120
150
180
TIME (HR.)
All &
HCO
Control
⁻TRACE METALS [⁻TM]
⁻Si
⁻EDTA+
⁻VITAMINS
All
⁻P
CONTROL
⁻N
⁻INORGANIC
CARBON [HCO$_3$]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TIME(HR.)
All
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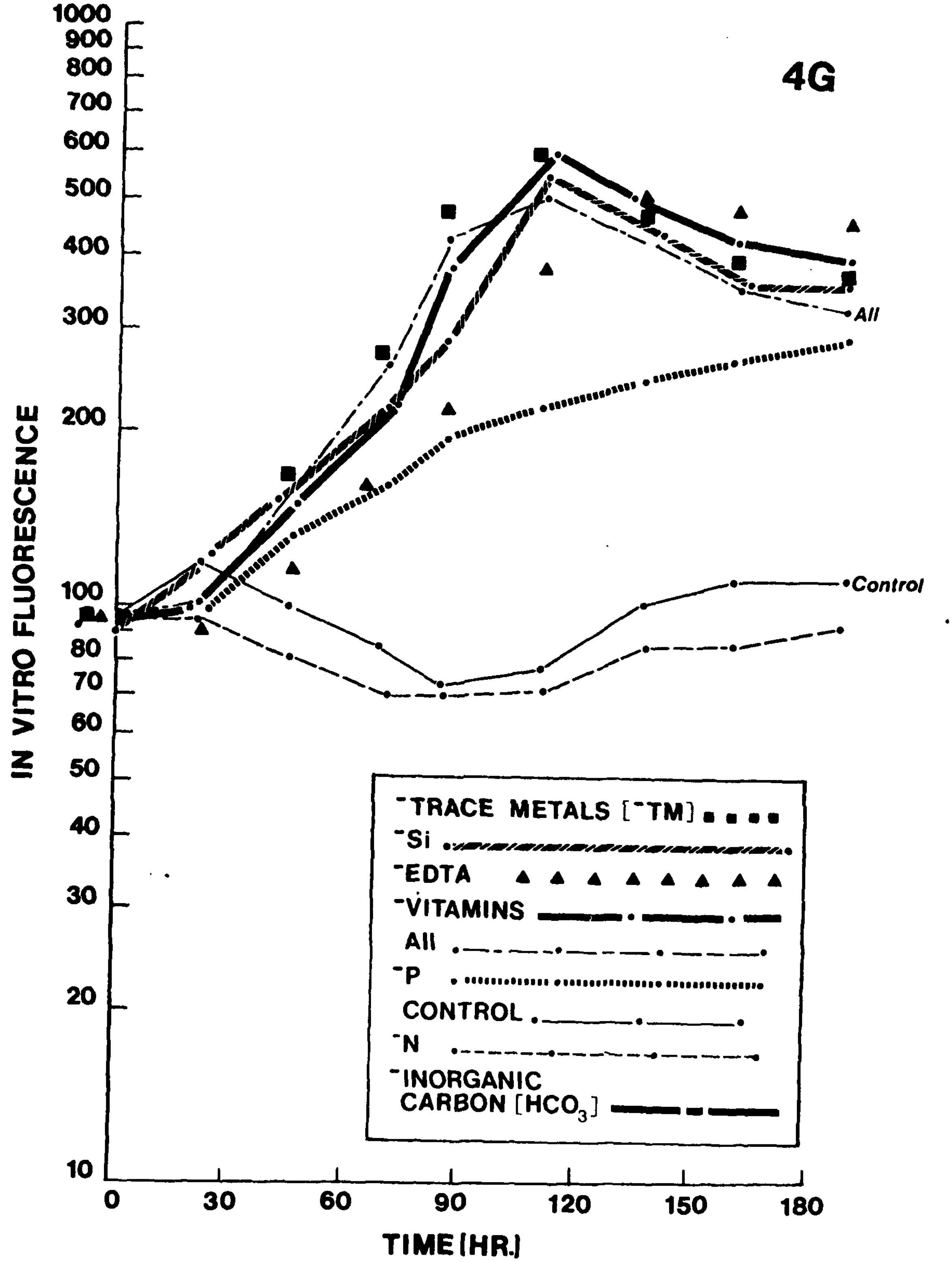
-TRACE METALS [-TM]
-Si
-EDTA
-VITAMINS
All
-P
CONTROL
-N
-INORGANIC CARBON [HCO3]



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TIME (HR.)
All
Control
⁻TRACE METALS [⁻TM]
⁻Si
⁻EDTA
⁻VITAMINS
All
⁻P
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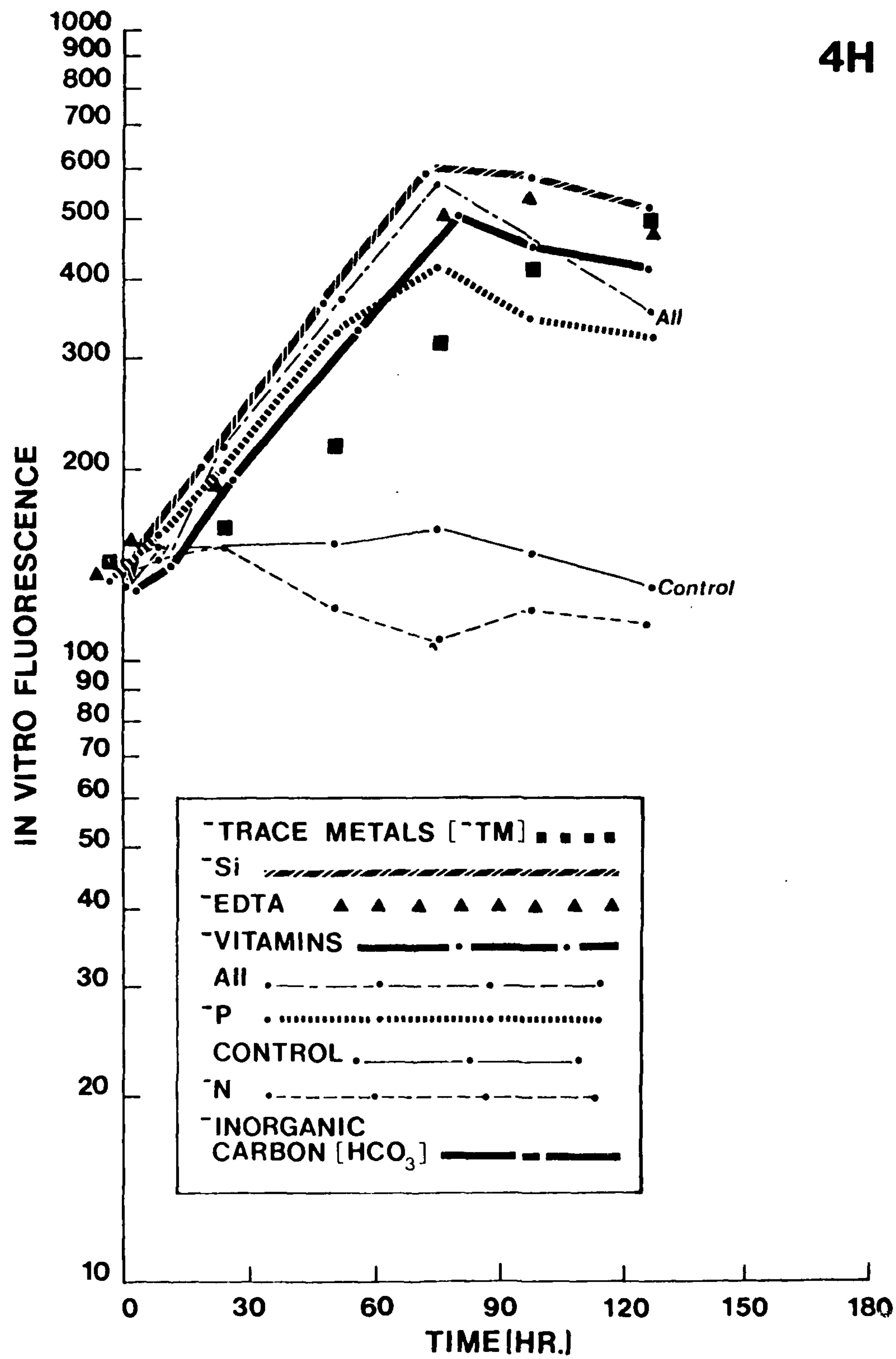
⁻INORGANIC CARBON [HCO_3]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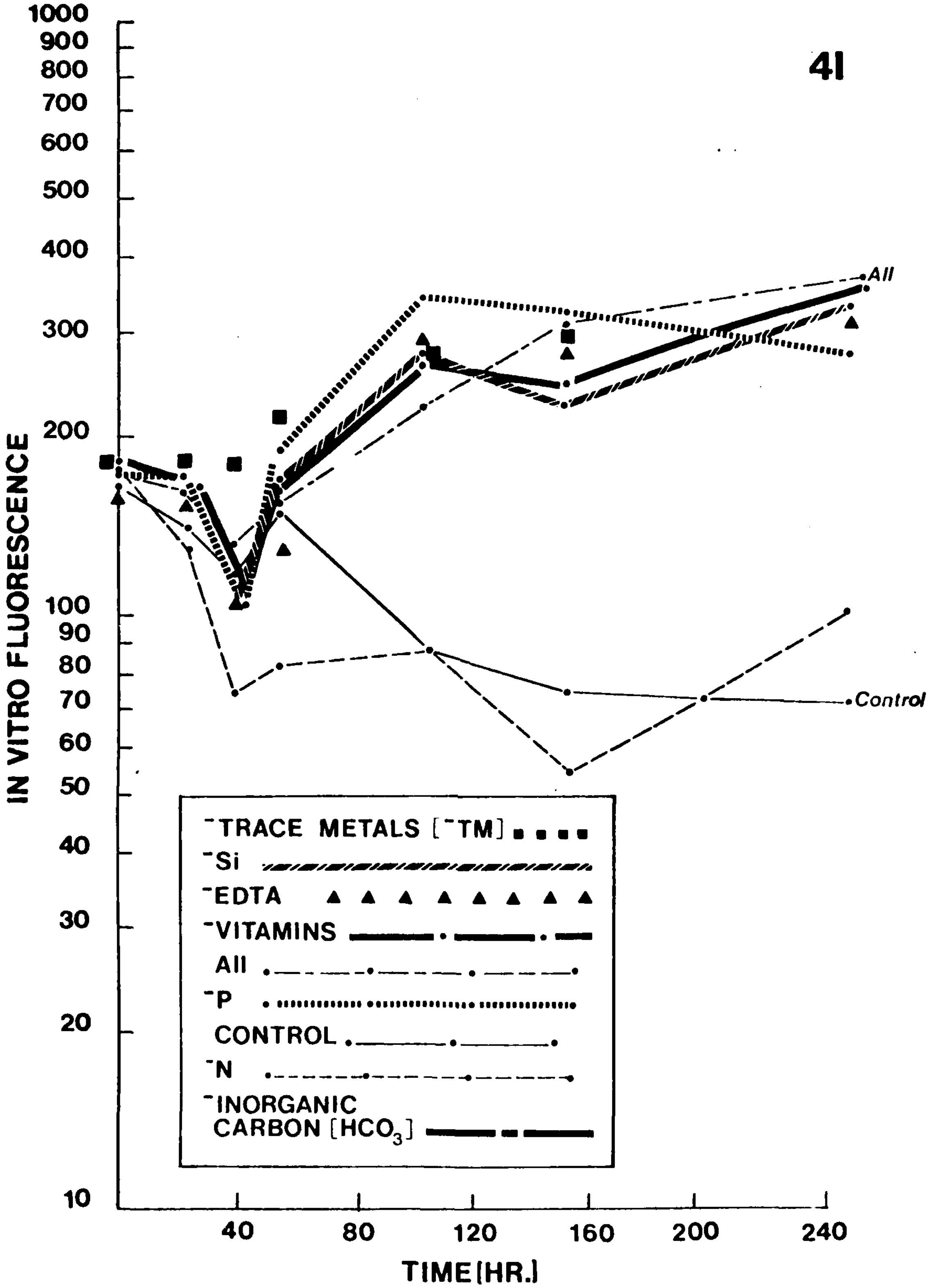
¯INORGANIC CARBON [HCO3]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IN VITRO FLUORESCENCE
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All
Control
⁻TRACE METALS [⁻TM]
⁻Si
⁻EDTA
⁻VITAMINS
All
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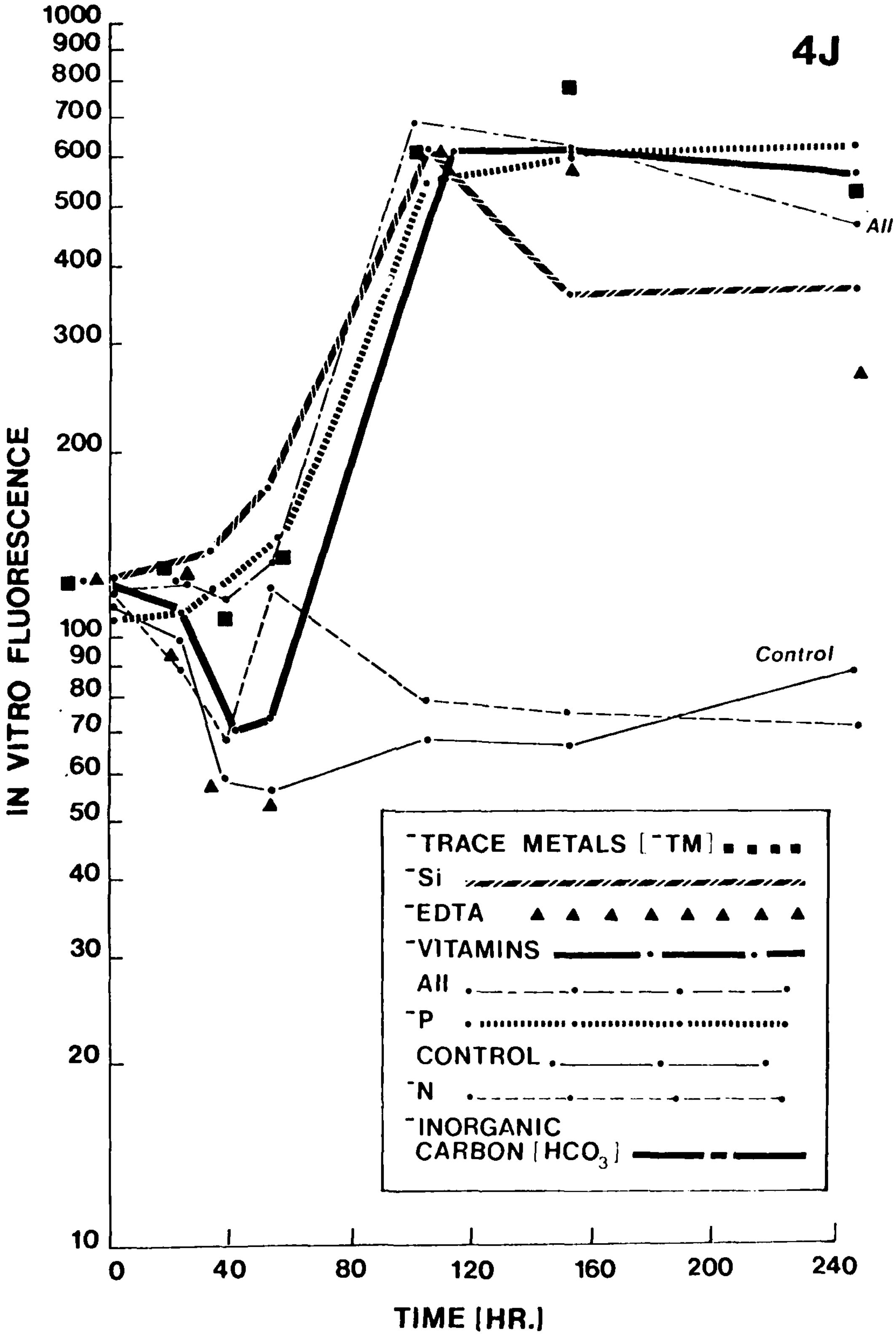
CONTROL
⁻N
⁻INORGANIC CARBON [HCO_3]


4J
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TIME [HR.]
All
Control
⁻TRACE METALS [⁻TM]
⁻Si
⁻EDTA
⁻VITAMINS
All
⁻P
CONTROL
⁻N
⁻INORGANIC CARBON [HCO3]

APPENDIX 5

Experimental Data

Chemical and biological data for the various experimental studies.

Table	Date	Area
5A	October	Near the New Orleans canals and the open water reference station
5B	November	Lake Borgne to Rigolets transect
5C	November	Near the New Orleans canals
5D	December	Pass Manchac to Lake Maurepas transect
5E	December	Pass Manchac to Lake Maurepas transect
5F	July	Pass Manchac Drogue study
5G	Annual	Lakewide summary of some of the chlorophyll concentration hourly photosynthetic production and assimilation ratios for the study

Table 5a. Experimental Eutrophication Study (10/12/78)

Stn. Depth	NH_3	$NO_2 + NO_3$	DON	PN	TN	PO_4	TDP	TP	SiO_2	Cond.	pH
	μg/1									(μmho/cm)	
E#9 surf.											8.00
3 M	20	40	503	401	964	23	24	44	576	6540	7.95
E#10 surf.	70	10	546	123	749	92	242	76	3666	7250	8.05
3.5 M	10	52	591	246	899	38	48	51	2848	3880	7.95
E#12 surf.	0	0	493	109	602	56	58	79	2988	5700	8.15
1.0 M	0	0	478	119	597	48	53	46	3063	3880	8.25
E#11 surf.	3	17	613	262	895	86	106	137	2454	7480	8.30
2.5 M	10	2	606	185	803	107	179	125	2939	7950	8.30
E#12-A surf.	8	24	593	123	748	57	67	75	3242	6120	8.40
4.0 M	0	13	427	---	400	38	44	54	3161	5080	8.20
E#12-B surf.	3	8	397	80	488	46	59	62	3129	5280	8.55
2.0 M	3	62	357	27	449	44	57	86	3161	8260	8.45

	Chlor. a (μg/1)	Chlor. c (μg/1)	Phaeophy. (μg/1)	^{14}C Productivity (μg/1 hr) Light	Dark	Dissolv.	Assim. Ratio (hr^{-1})
E#9 surf.	13.06	3.25	4.43	25.57	2.06	6.35	2.0
3 M	11.70	1.94	3.10	-----	----	----	---
E#10 surf.	21.71	6.07	5.39	12.47	3.13	8.05	0.6
3.5 M	11.87	3.39	0.75	21.74	5.22	5.88	1.8
E#12 surf.	9.66	1.22	3.36	48.25	2.06	4.74	5.0
1.0 M	8.30	3.21	12.92	38.09	2.37	3.87	4.6
E#11 surf.	15.08	3.97	13.24	41.74	1.84	4.41	2.8
2.5 M	13.69	5.62	2.83	25.22	1.42	4.36	1.8
E#12-A surf.	10.33	3.92	2.67	44.99	2.38	4.86	4.4
4.0 M	11.92	4.04	1.66	17.32	1.75	3.31	1.4
E#12-B surf.	-----	----	----	16.14	1.92	2.54	---
2.0 M	-----	----	----	21.53	2.02	2.44	---

Table 5B. Lake Borgne-Rigolets Transect (11/2/78)

Stn. Depth	NH_3	$NO_3 + NO_3$	DON	PN	TN	PO_4	TDP	TP	SiO_2	Cond.	pH
	←				µg/1				→	(µmho/cm)	
MS#4 surf.	33	48	376	0	457	18	23	36	4274	10600	7.78
5 M	--	60	255	212	560	37	36	37	4930	10800	7.78
E#1 surf.	37	54	323	240	654	32	45	45	5742	10600	7.95
E#2 surf.	0	68	266	197	599	12	16	36	5054	10900	8.11
10 M	3	19	264	53	339	9	16	29	3484	13200	8.11
E#4 surf.	0	49			356	13	21	38	4613	13400	8.46
1.5 M	11	14	442	250	717	14	19	42	5017	13500	8.36
E#3 surf.	15	12	422	110	559	19	17	35	5933	13900	8.12
E#13 surf. Pearl R. Mouth	24	100	429	297	850	7	10	35	4577	10300	8.15

	Chlor. a (µg/1)	Chlor. c (µg/1)	Phaeophy. (µg/1)	Phaeophy. Fract. (%)
MS#4 surf.	5.62	1.21	2.21	28.2
5 M	4.60	1.78	1.07	18.8
E#1 surf.	6.56	2.52	3.10	32.1
E#2 surf.	9.56	2.40	8.08	45.8
10 M	8.36	3.32	6.69	44.5
E#4 surf.	6.27	1.39	5.02	44.5
1.5 M	3.54	2.06	2.35	39.9
E#3 surf.	4.93	1.50	5.50	52.7
E#13 surf.	8.76	3.02	7.32	45.5

Table 5B. (Continued). The Rigolets-Lake Borgne Transfer Study (11/2/78)

Bottle No. and Time		Chlor. a (μg/l)	Phaeophy. (μg/l)	^{14}C productivity (μg/l hr) Light	Dark	Dissolv.	Assim. Ratio (hr^{-1})
T=0	#1	----	0.20				
	#2	----	0.10				
	#3	----	0.10				
	#4	1.06	----				
T=1	#1			13.05	2.67	13.40	
	#2	No samples taken		15.06	1.98	12.30	
	#3			12.60	1.73	12.16	
	#4			13.22	3.00	11.75	
T=2	#1	----	----	15.16	1.37	5.82	
	#2	----	----	11.54	0.91	4.29	
	#3	----	0.20	10.96	1.58	5.31	
	#4	----	0.20	12.74	1.40	7.33	
T=4	#1	----	0.67	14.10	1.03	3.32	
	#2	----	0.20	11.18	0.45	3.03	
	#3	----	0.20	10.56	1.01	3.06	
	#4	0.19	0.47	11.04	0.80	3.01	
T=6	#1	----	----	10.94	0.67	1.79	
	#2	----	----	12.09	0.43	1.60	
	#3	----	----	12.06	0.82	2.44	
	#4	----	----	12.15	0.72	1.30	

Bottle #1: The Rigolets water and organisms
Bottle #2: The Rigolets water and Lake Borgne organisms
Bottle #3: Lake Borgne water and organisms
Bottle #4: Lake Borgne water and The Rigolets organisms

Table 5B. (Continued). The Rigolets-Lake Borgne Transfer Study (11/2/78)

Bottle No. and Time		NH_3	$NO_2 + NO_3$	DON	PN	TN	PO_4	TDP	TP	SiO_2	Cond.	pH
		←			μg/l					→	(μmho/cm)	
T=0	#1	0	89	297	172	558	12	15	24	4610	7720	8.05
	#2	15	134	422	0	571	16	17	20	5187	6340	8.60
	#3	11	90	333	93	427	16	17	24	5085	12400	8.40
	#4	0	45	274	14	333	16	22	22	3973	8520	8.70
T=1	#1											8.30
	#2		No samples taken									8.25
	#3											[illegible]
	#4											8.35
T=2	#1	0	31	137	315	483	14	16	35	3307	11400	8.45
	#2	8	0	321	192	521	16	22	28	4347	10800	8.45
	#3	3	16	340	232	591	15	25	17	4347	9700	8.55
	#4	0	4	384	0	388	16	22	30	4240	13600	8.52
T=4	#1	0	2	301	96	399	17	22	27	4373	9350	8.41
	#2	12	0	333	52	397	15	20	25	4984	11000	8.50
	#3	12	16	367	242	637	14	22	26	5084	13900	8.69
	#4	0	0	259	344	603	14	28	30	4300	13900	8.64
T=6	#1	15	14	313	362	704	33	26	26	6232	8250	8.50
	#2	5	12	271	69	357	14	14	16	5117	4820	8.45
	#3	13	16	384	17	430	14	12	19	5084	5900	8.65
	#4	0	13	345	52	410	7	10	21	2755	6550	8.40

Bottle #1: The Rigolets water and organisms
Bottle #2: The Rigolets water and Lake Borgne organisms
Bottle #3: Lake Borgne water and organisms
Bottle #4: Lake Borgne water and The Rigolets organisms

Table 5C. Experimental Study (11/20/78)

Stn. Depth	NH_3	$NO_2 + NO_3$	DON	PN	TN	PO_4	TDP	TP	SiO_2	Cond.	pH
	←				µg/1				→	(µmho/cm)	
MS#2 0.5 M	0	6	192	24	222	18	22	43	3050	3600	7.70
E#14 0.5 M	21	3	143	312	477	34	40	70	3083	4560	7.85
MS#3 0.5 M [canal]	3	13	298	50	364	27	40	59	700	7500	8.15
MS#3 0.5 M [lakewater]	0	13	244	90	347	24	32	60	685	6400	8.10
E#15 0.5 M [Pont. Amuse. Pk.]	0	17	377	7	401	28	38	49	420	3450	8.15
S#7 0.5 M	287	110	364	---	---	182	203	---	470	5300	7.85

	Chlor. a (µg/1)	Phaeophy. (µg/1)	Phaeophy. Fract. (%)	Inorg. C (Mg/1)
MS#2 0.5 M	4.50	3.84	46.1	9.50
E#14 0.5 M	9.63	10.63	52.4	8.20
MS#3 0.5 M [canal]	7.34	2.35	24.2	10.34
MS#3 0.5 M [lakewater]	7.40	5.07	40.7	10.02
E#15 0.5 M	9.60	5.18	35.0	9.81
S#7 0.5 M	13.41	9.72	42.0	11.05

Table 5D. Transect from 7.5 Miles off Pass Manchac to Lake Maurepas (12/1/78; 0.5 M depth samples)

Station	NH_4	$NO_2 + NO_3$	DON	PN	TN	PO_4	TDP	TP	SiO_2	Cond. (µmho/cm)	pH
	←			µg/1					→		
Middle of Lake E#8	60	38	387	24	509	32	44	58	3250	1500	7.35
Amite River	56	77	328	228	689	24	37	53	6510	400	6.55
Tickfaw River	95	90	376	78	639	72	81	93	4500	800	6.85
Blind River	213	112	333	227	885	154	151	190	6614	530	7.00
MS#1	61	61	424	113	659	38	46	60	3177	1560	7.42
S#3	20	22	346	113	501	17	22	39	2950	5500	7.70
S#5	30	19	381	-	370	19	28	25	1010	3400	7.70

Station	Inorg. C (Mg/1)	DOC (Mg/1)	TOC (Mg/1)	Chlor. a (µg/1)	Phaeophy. (µg/1)	Phaeophy. Fract. (%)
Middle of Lake E#8	5.32			1.41	----	----
Amite River	5.62			2.86	1.27	30.7
Tickfaw River				3.12	----	----
Blind River	8.33			2.86	2.40	45.7
MS#1	6.10			3.73	0.40	9.7
S#3	9.24			2.83	0.13	4.5
S#5	8.09			3.40	1.07	23.9

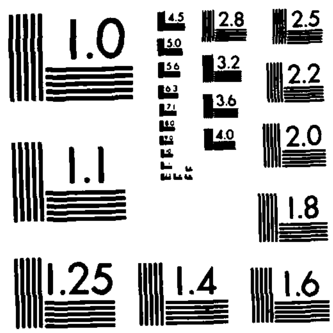
Table 5E. Pass Manchac-Lake Maurepas Transect Study (12/14/78)

Stn. Depth	NH_3	$NO_2 + NO_3$	DON	PN	TN	PO_4	TDP	TP	SiO_2	Cond.	pH
	←				µg/1				→	(µmho/cm)	
S#3 surf.	0	41	404	90	535	11	18	49	690	3800	7.25
2 M	14	62	367	120	563	25	32	59	950	5000	7.4
MS#1 surf.	108	98	409	384	999	58	63	40	235	1500	7.25
E#5 surf.	65	206	303	544	1118	55	54	121	3377	2540	7.30
E#6 surf.	67	105	603	37	812	46	48	73	2605	1980	7.30
E#8 surf.	90	198	366	105	759	82	104	110	4572	1100	7.2
2.5 M	99	149	292	111	651	57	61	77	2024	930	7.25
S#5 surf.	0	31	329	90	450	18	26	46	3130	5500	8.10

	Chlor. a (µg/1)	Chlor. c (µg/1)	Phaeophy. (µg/1)	Phaeophy. Fract. (%)
S#3 surf.	5.91	1.03	6.41	52.0
2 M	5.66	0.18	3.67	39.3
MS#1 surf.	2.02	1.94	3.27	61.8
E#5 surf.	3.95	1.28	4.27	52.0
E#6 surf.	2.82	2.15	3.54	[illegible]
E#8 surf.	1.16	0.91	1.87	61.6
2.5 M	—	—	—	—
S#5 surf.	8.64	1.95	4.27	[illegible]

Bottle #1: S#3 organisms and water; Bottle #2: S#3 organisms plus E#8 water;
Bottle #3: E#8 organisms and water; Bottle #4: E#8 organisms plus S#3 water.

AD-A123 375 ENVIRONMENTAL ANALYSIS OF LAKE PONTCHARTRAIN LOUISIANA 6/7
ITS SURROUNDING WE..(U) LOUISIANA STATE UNIV BATON
ROUGE COASTAL ECOLOGY LAB J H STONE FEB 80
UNCLASSIFIED LSU-CEL-80-08-VOL-1 DACW29-77-C-0253 F/G 6/6 NL



MICROCOPY RESOLUTION TEST CHART
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Table 5E. (Continued) December Transfer Study Pass Manchac-Lake Maurepas (12/14/78)

Bottle No. and Time		Chlor. a (μg/l)	Phaeophy. (μg/l)	^{14}C productivity (μg/l hr) Light	Dark	Dissolv.	Assim. Ratio (hr^{-1})
T=0	#1	0.88	2.50				
	#2	0.07	0				
	#3	0.34	0.9				
	#4	1.43	2.6				
T=1	#1	0.90	1.40	3.54	1.75	4.67	3.9
	#2	0.18	0	3.70	1.40	5.75	20.6
	#3	0.29	0	5.62	1.02	3.54	19.4
	#4	2.24	0.59	9.13	1.81	3.27	4.1
T=2	#1	1.38	0.97	7.21	1.14	2.37	5.2
	#2	0.29	0	4.89	0.56	2.64	16.9
	#3	0.29	0	----	----	----	----
	#4	1.45	0.33	15.09	1.02	1.45	10.4
T=4	#1	1.12	0.97	10.28	0.43	1.68	9.2
	#2	0.55	0	----	----	----	----
	#3	0.58	0	2.33	0.14	0.78	4.0
	#4	1.43	0	8.69	0.31	0.94	6.1
T=5	#1	0.82	0.93	10.51	0.28	1.76	12.8
	#2	0.18	0	4.43	0.23	1.16	24.6
	#3	0.50	0	1.17	0.14	0.56	2.3
	#4	1.96	0	8.19	0.24	0.97	4.2

Bottle #1: S#3 organisms and water; Bottle #2: S#3 organisms plus E#8 water;
Bottle #3: E#8 organisms and water; Bottle #4: E#8 organisms plus S#3 water.

Table 5E. (Continued). Pass Manchac-Lake Maurepas Transfer Study (12/14/78)

Bottle No. and Time		NH_3	$NO_2 + NO_3$	DON	PN	TN	PO_4	TDP	TP	SiO_2	Cond. (µmho/cm)	pH
		←				µg/l				→		
T=0	#1	8	100	209	16	341	39	47	48	2880	3640	7.60
	#2	19	50	381	—	—	48	50	—	2658	3950	7.65
	#3	93	203	324	66	686	79	93	84	5013	880	7.40
	#4	70	198	397	—	631	62	81	86	3840	1320	7.30
T=1	#1	13	130	270	184	597	42	52	62	2933	4040	7.60
	#2	55	120	228	17	420	56	47	61	3040	2650	7.70
	#3	88	195	345	16	644	66	66	93	3907	780	7.40
	#4	50	118	252	125	545	48	48	79	2073	1410	7.35
T=2	#1	0	48	338	71	457	43	43	52	2651	5440	7.70
	#2	33	45	323	426	827	50	49	65	2796	4880	7.70
	#3	117	121	345	71	654	71	78	82	3808	1090	7.45
	#4	63	106	204	338	711	60	65	80	3470	1780	7.45
T=4	#1	7	63	206	178	454	37	37	44	2892	3950	7.65
	#2	8	72	227	353	660	34	35	53	2023	3080	7.70
	#3	45	193	449	0	687	69	70	70	3716	718	7.48
	#4	101	111	252	259	723	58	56	66	3387	965	7.35
T=5	#1	64	109	438	56	667	55	50	—	3536	5150	7.60
	#2	19	49	558	—	670	46	54	—	2721	2820	7.65
	#3	77	78	518	93	766	59	64	81	3419	1210	7.40
	#4	96	186	406	521	1209	49	48	112	3280	1580	7.35

Bottle #1: S#3 organisms and water; Bottle #2: S#3 organisms plus E#8 water;
Bottle #3: E#8 organisms and water; Bottle #4: E#8 organisms plus S#3 water.

Table 5F. Pass Manchac Drouge Study (7/19/78)

Time & Depth		NH_4	$NO_2 + NO_3$	DON	PN	TN	PO_4	TDP	TP	SiO_2	Cond.
		µg/1									(µmho/cm)
T=0	surf.	53	143	559	164	919	16	27	48	2140	1230
	2.5 M	170	73	512	47	802	17	24	44	2940	1250
T=1	surf.	39	78	421	180	718	16	24	52	1882	1150
	2.5 M	43	183	497	300	1023	16	43	48	1788	1180
T=2	surf.	48	138	692	60	938	33	40	49	2964	1020
	2.5 M	60	262	300	200	822	13	47	49	2940	1130
T=3	surf.	43	111	457	380	991	27	29	57	2964	1260
	2.5 M	25	145	455	160	785	8	23	48	1435	1210
T=4	surf.	38	99	596	---	648	15	66	31	2825	1400
	2.5 M	14	85	547	134	780	16	32	41	794	1430
T=5	surf.	35	71	648	73	827	22	28	52	----	1460
	2.5 M	70	95	442	49	656	32	44	50	1238	1490

Time & Depth		Chlor. a (µg/1)	Phaeoph. (µg/1)	Phaeophy. Fract. (%)	73% C-14 Productivity (µg/1 hr) Particulate	Dark	pH	Inorg. C (Mg/1)
T=0	surf.	6.53	5.07	43.7	13.80	0.38	7.19	2.20
	2.5 M	7.32	4.20	36.5	10.99	0.24	7.17	1.86
T=1	surf.	12.70	11.95	48.5	13.74	0.28	7.23	2.09
	2.5 M	12.40	10.35	45.5	-----	----	7.23	2.20
T=2	surf.	10.48	8.21	43.9	-----	----	7.23	2.45
	2.5 M	10.44	7.08	40.4	12.36	0.38	7.23	2.09
T=3	surf.	12.44	9.21	42.5	14.01	0.80	7.23	2.20
	2.5 M	10.69	7.54	41.4	-----	----	7.23	2.20
T=4	surf.	12.76	7.41	36.7	-----	----	7.36	1.41
	2.5 M	10.18	6.61	39.4	11.73	0.26	7.23	2.20
T=5	surf.	13.85	8.14	37.0	13.12	0.31	7.23	1.86
	2.5 M	12.18	6.47	34.7	-----	----	7.25	2.08

Table 5G. Chlorophyll and Photosynthetic Production (*In Situ* or Simulated *in situ* with 221 microeinstein.$M^{-2}.Sec^{-1}$) Data

Date Station - Depth	Chlorophyll *a* (ppb)	Particulate C-14 Production (ppb)	Assimilation Ratio	Dissolved C-14 Production (ppb)
2/14 S#3 surf.	3.93	3.7125	0.94	
2/14 MS#1 surf.	5.57	1.5481	0.28	
1.0M	5.46	1.9387	0.36	
3/14 S#5 surf.	14.32	4.3834	0.31	2.33
1115 hrs. 0.5M	16.91	14.3438	0.85	2.16
surf.	18.57	3.4787	0.19	3.35
1415 hrs. 0.5M	20.88	14.6072	0.70	5.60
3/15 S#3 surf.	5.58	22.9274	4.11	2.34
1.5M	11.82	56.33	4.76	
MS#1 surf.	6.14	8.4376	1.37	0.57
1.0M	4.06	10.4935	2.58	0.20
S#5 surf.	21.42	20.4586	0.96	2.92
1.5M	19.76	61.4787	3.11	
S#6 surf.	17.22	22.0119	1.28	4.24
1.5M	8.48	35.3070	4.16	
MS#2 surf.	19.7	25.7301	1.31	6.19
1.5M	17.54	78.9263	4.50	8.51
3/16 MS#1 surf.	5.59	12.3913	2.22	1.83
0.5M	4.30	17.2453	4.01	0.93
4/25 MS#2 surf.	7.86	12.3520	1.57	3.90
2.0M	9.04	26.5598	2.94	3.02
MS#3 surf.	10.12	7.6419	0.76	2.27
1.0M	9.61	38.9003	4.05	6.60
4/26 MS#3 [Behind Seabrook Br.] surf.	9.87	30.1407	3.05	9.814
1105 hrs. 1.0M	20.24	47.0876	2.33	21.686
In Situ MS#3 surf.	9.87	47.5478	4.82	14.13
0.5M	≈15.06	19.8257	≈1.32	
1.0M	20.24	2.9176	0.14	9.34

Table 5G. (Continued). Chlorophyll and Photosynthetic Production

Date Station - Depth	Chlorophyll a (ppb)	Particulate C-14 Production (ppb)	Assimilation Ratio	Dissolved C-14 Production (ppb)
4/27 MS#4 [Below U.S.				
90 Br.] surf.	8.45	13.2053	1.56	2.494
<u>In Situ</u> MS#4 0.75M				
[U.S. 90 Br.]	8.60	25.4964	2.96	1.821
1040 hrs. surf.	8.45	8.8547	1.05	2.10
1.5M	8.74	14.8838	1.70	2.11
4/28 S#10 surf.	9.61	40.5511	-.22	4.20
1.5M	8.20	24.1548	2.94	4.45
S#12 surf.	7.29	12.3994	1.70	2.36
1.5M	6.50	31.8775	4.90	2.86
MS#4 surf.	7.58	17.3992	2.30	6.974
1.5M	7.80	34.0739	4.37	2.973
S#13 surf.	4.46	28.0424	6.29	4.226
2.0M	6.70	20.4091	3.05	6.781
S#9 surf.	10.98	32.3144	2.94	5.097
1.5M	12.98	36.2194	2.79	5.259
S#8 surf.	12.95	35.1806	2.72	4.108
2.0M	15.19	51.6874	3.40	5.725
MS#3 surf.	9.54	51.6779	5.42	5.418
1.5M	8.99	53.4544	5.94	4.614
5/23 MS#2 surf.	8.27	4.603	0.56	8.149
<u>In Situ</u> 1.0M	14.59	5.7931	0.40	5.36
1220 hrs. 2.5M	10.99	3.1550	0.29	1.899
5/23 MS#2 surf.	8.27	7.3773	0.89	1.699
1050 hrs. 1.0M	14.59	10.2192	0.70	1.112
5/24 MS#4 surf.	9.12	15.1619	1.66	8.49
<u>In Situ</u> 0.5M	11.85	20.5728	1.74	2.33
1.5M	12.46	4.1879	0.34	
5/24 MS#4 surf.	9.12	17.6162	1.93	1.43
1400 hrs. 1.5M	12.46	13.2145	1.06	1.35

Table 5G. (Continued). Chlorophyll and Photosynthetic Production

Date Station - Depth	Chlorophyll a (ppb)	Particulate C-14 Production (ppb)	Assimilation Ratio	Dissolved C-14 Production (ppb)
6/20 MS#1 surf.	11.20	48.035	4.29	16.216
2.0M	13.07	28.657	2.19	23.040
6/20 MS#1 surf.	11.20	23.940	2.14	21.142
In Situ 0.75M	10.74	28.3237	2.64	16.51
2.0M	13.07	7.532	0.58	16.23
6/22 MS#3 surf.	8.68	30.052	3.46	5.49
In Situ 1.0M	8.81	23.8807	2.71	6.48
2.7M	8.44	14.9763	1.77	7.85
6/22 MS#3 surf.	8.68	14.0685	1.62	8.02
3.0M	8.44	9.5085	1.13	26.87
7/18 S#2 surf.	7.32	25.63	3.50	
2.5M	6.31	29.6576	4.70	
7/18 MS#1 surf.	9.32	10.8912	1.17	5.6822
2.5M	9.10	8.0119	0.88	3.2960
S#3 surf.	6.52	24.5165	3.76	
3.0M	7.14	17.9162	2.51	
MS#2 surf.	5.98	16.9002	2.83	8.6315
3.0M	6.56	31.8766	4.86	8.8663
7/20 MS#3 surf.	11.06	32.9465	2.98	30.0513
2.5M	10.77	49.1071	4.56	30.3431
S#9 surf.	10.44	50.0995	4.80	11.5313
2.5M	11.13	40.2142	3.61	5.0959

Table 5G. (Continued). Chlorophyll and Photosynthetic Production

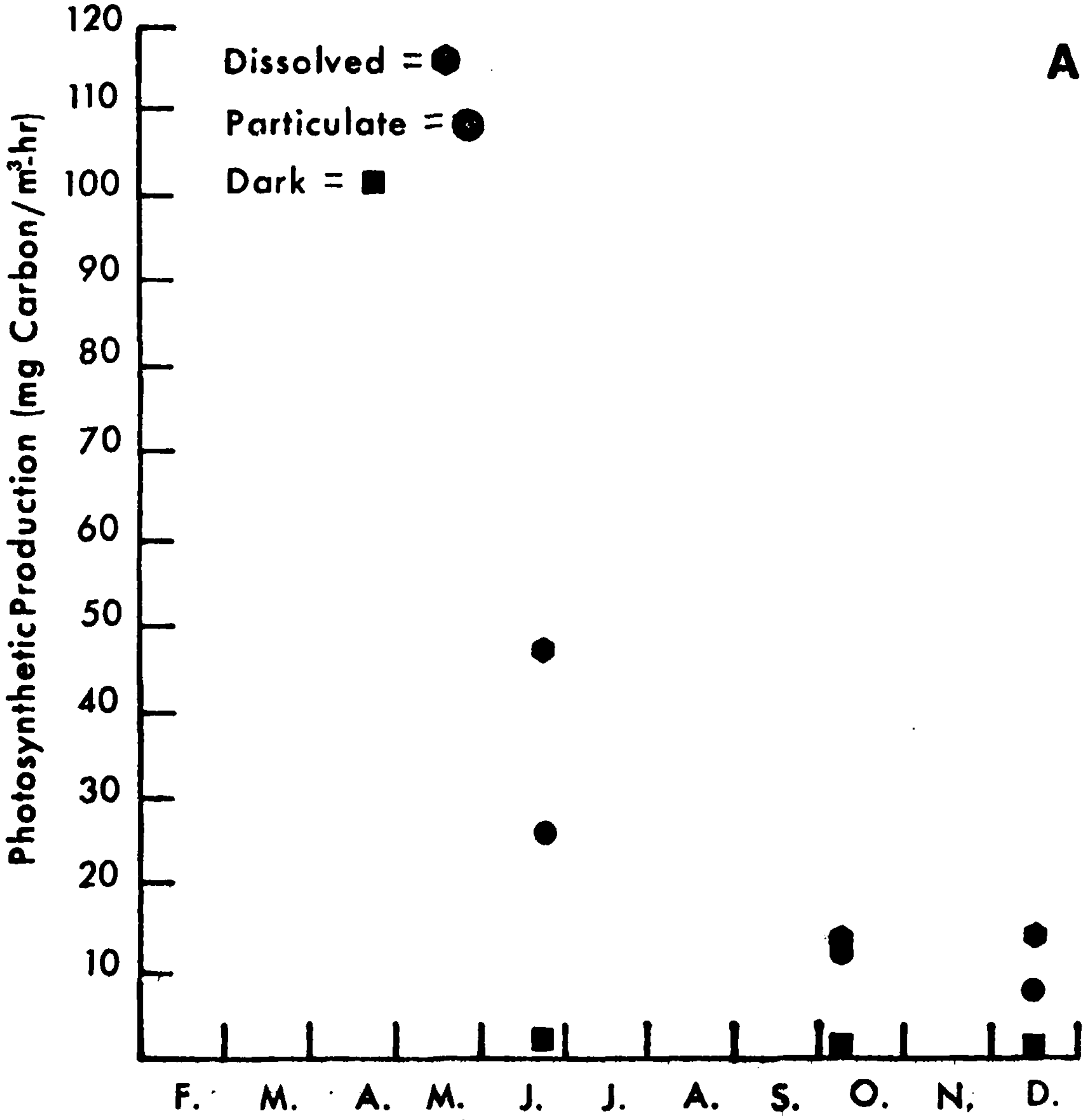
Date Station - Depth	Chlorophyll a (ppb)	Particulate C-14 Production (ppb)	Assimilation Ratio	Dissolved C-14 Production (ppb)
9/19 MS#2 surf.	9.86	7.26	0.74	1.57
2.5M	10.44	13.10	1.25	1.42
9/19 MS#2 surf.	9.86	11.54	1.17	5.01
In Situ 0.75M	9.03	13.07	1.86	4.24
2.5M	10.44	5.40	0.52	3.27
9/20 MS#4 surf.	8.48	8.93	1.05	6.12
3.0M	6.53	11.56	1.77	4.50
9/20 MS#4 surf.	8.48	21.89	2.58	5.15
In Situ 1.0M	8.57	25.13	2.93	3.68
2.7M	6.53	6.67	1.02	2.22
9/21 MS#3 surf.	17.73	39.85	2.25	10.72
3.0M	11.53	41.95	3.64	14.90
9/21 MS#3 surf.	17.73	99.81	5.63	9.39
In Situ 1.0M	14.72	51.06	3.47	5.12
2.7M	11.53	16.50	1.43	---
9/21 S#2 1.0M	9.64	26.57	2.76	

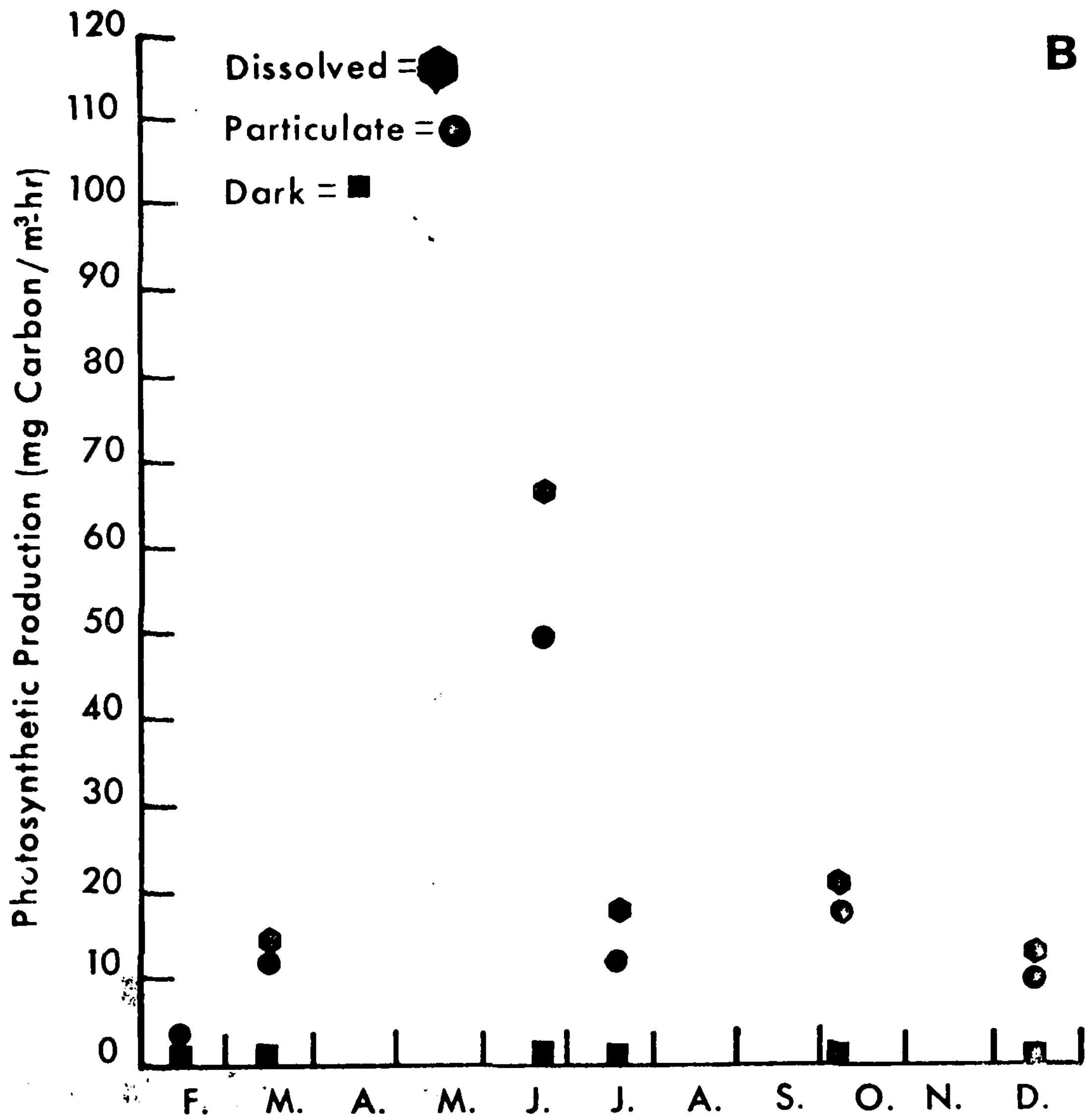
APPENDIX 6

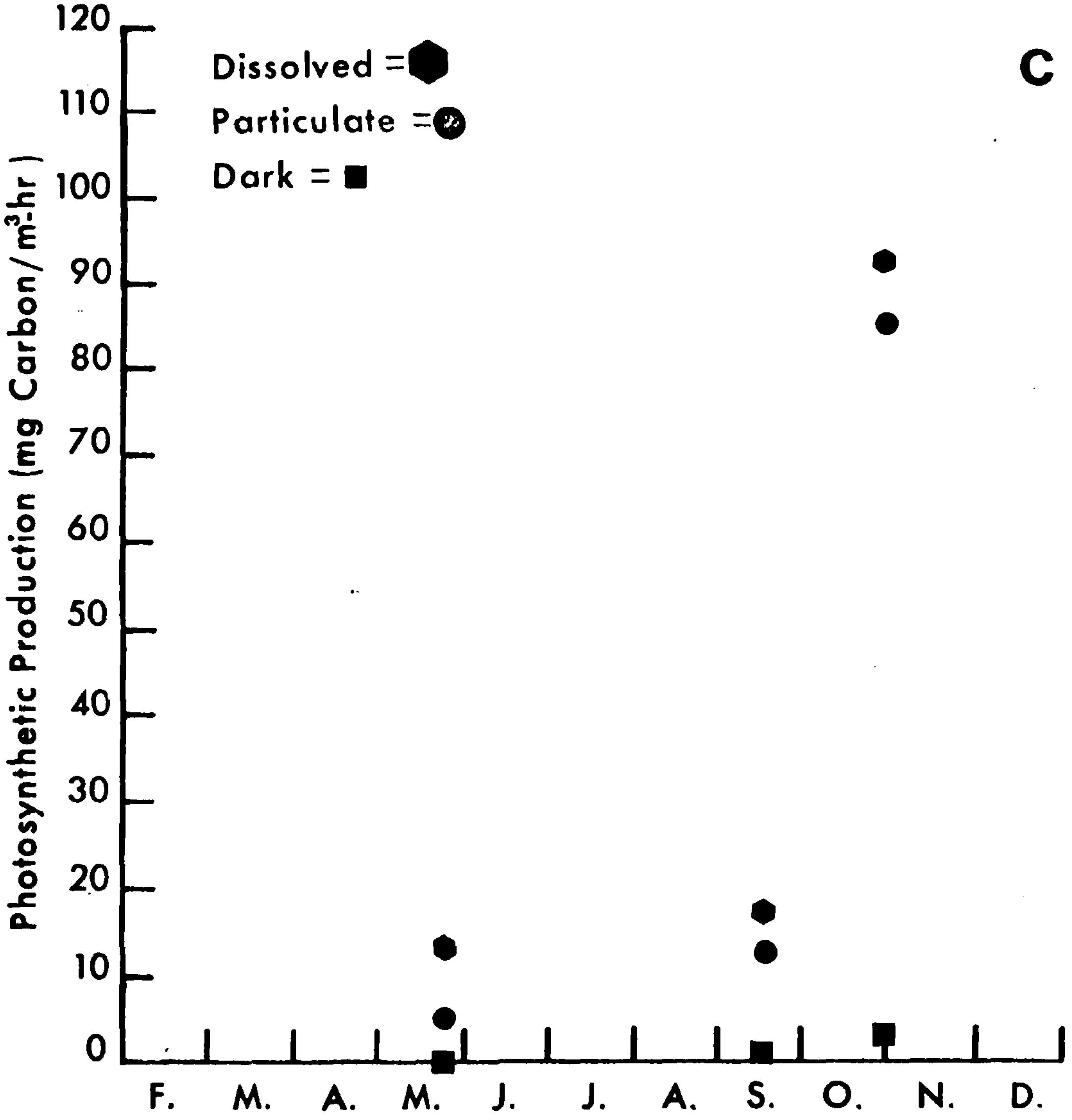
In Situ Productivity

Photosynthetic production during different months measured in situ and in the incubator. The data for each month are arranged cumulatively (vertically). The distance between the circle and the square is the amount of particulate production. The distance between the hexagon and the circle is the amount of production formed as dissolved material.

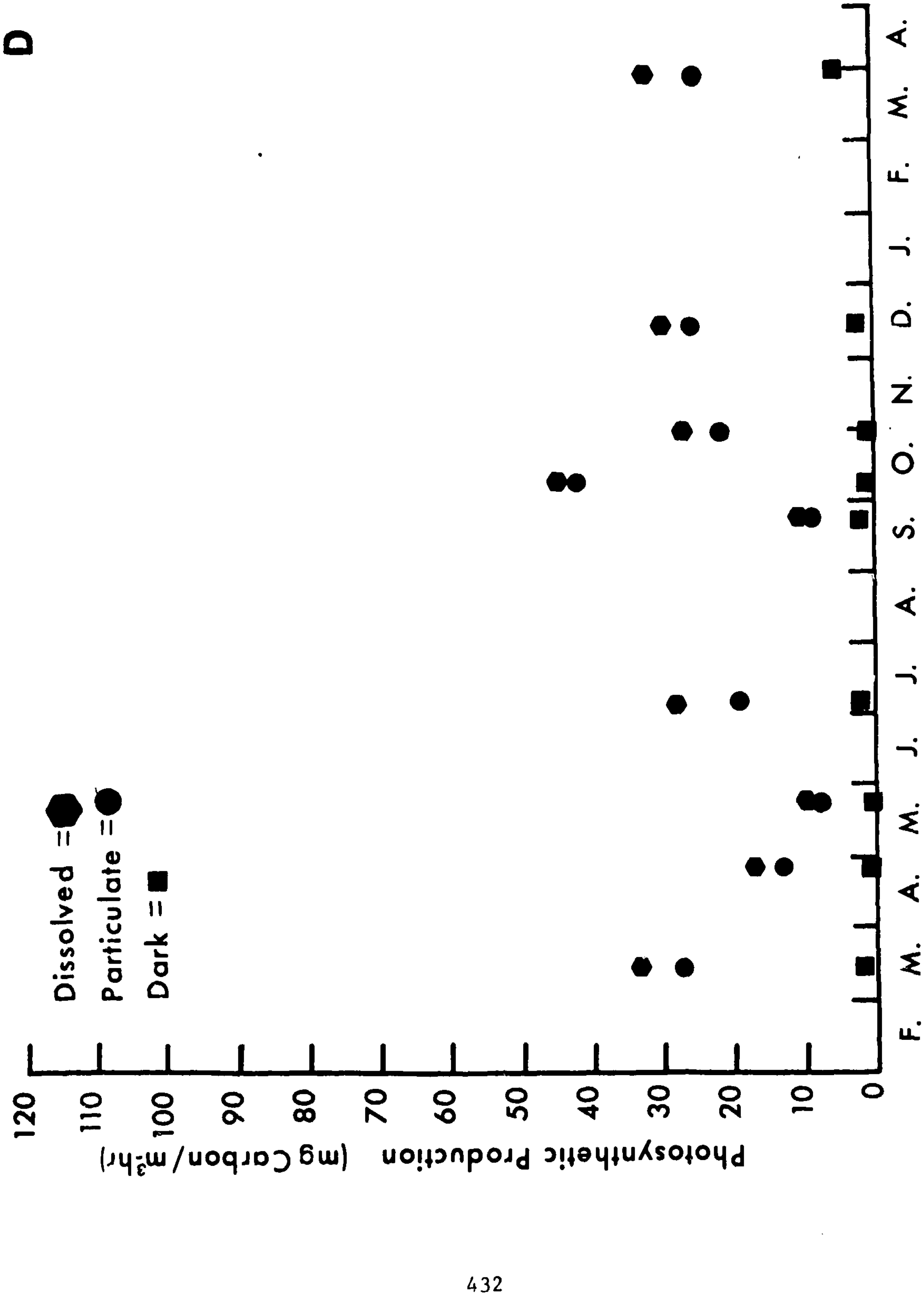
Figure	Station	Depth	Conditions
A	MS1	Surface	in situ
B	MS1	Surface	73% light intensity in the incubator
C	MS2	Surface	in situ
D	MS2	Surface	73% light intensity in the incubator
E	MS3	Surface	in situ
F	MS3	Surface	73% light intensity in the incubator
G	MS4	Surface	in situ
H	MS4	Surface	73% light intensity in the incubator

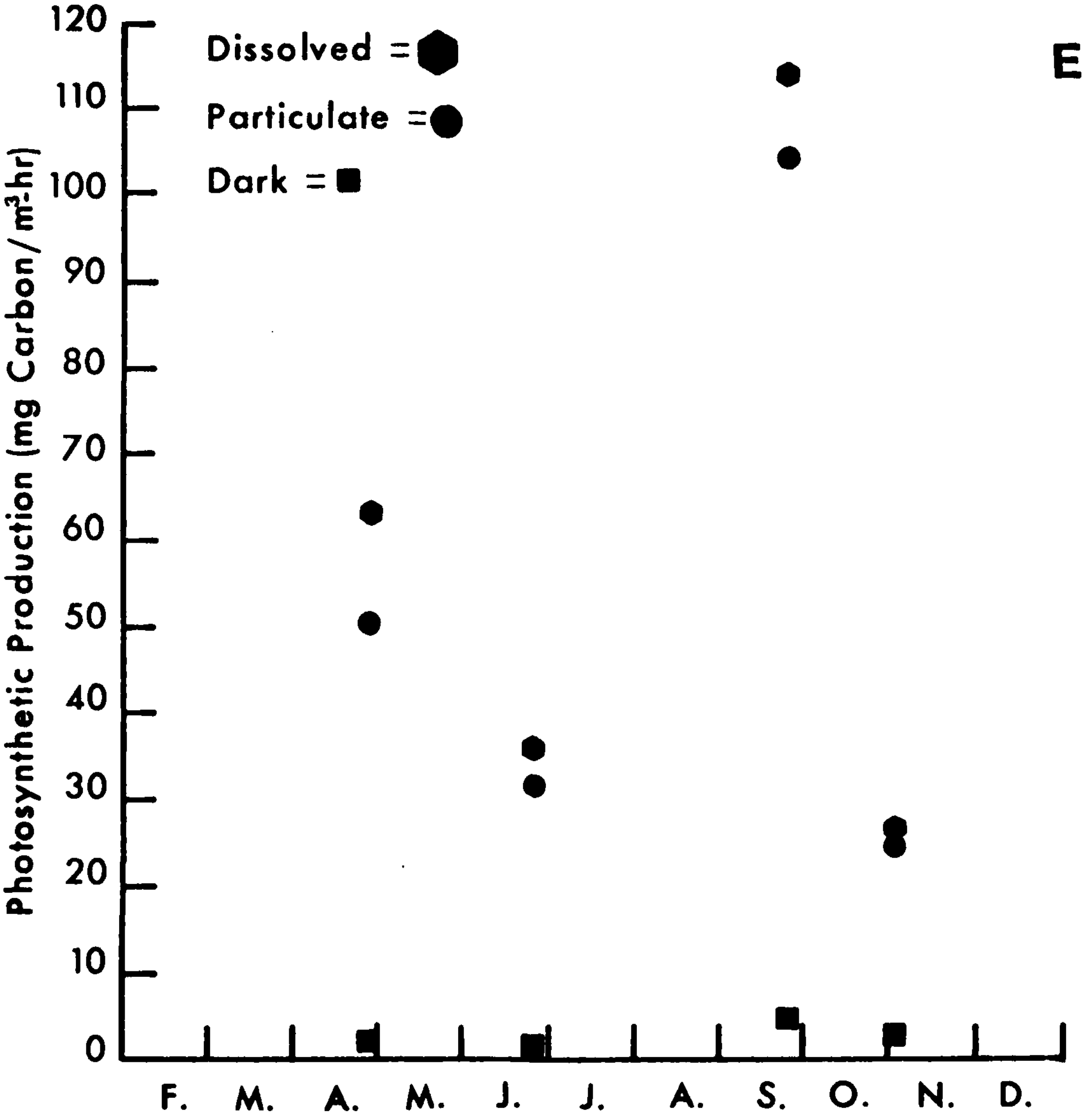

Dissolved =
Particulate =
Dark =
A
Photosynthetic Production (mg Carbon/m³-hr)
120
110
100
90
80
70
60
50
40
30
20
10
F.
M.
A.
M.
J.
J.
A.
S.
O.
N.
D.


B
Dissolved =
Particulate =
Dark =
Photosynthetic Production (mg Carbon/m³·hr)
120
110
100
90
80
70
60
50
40
30
20
10
0
F.
M.
A.
M.
J.
J.
A.
S.
O.
N.
D.

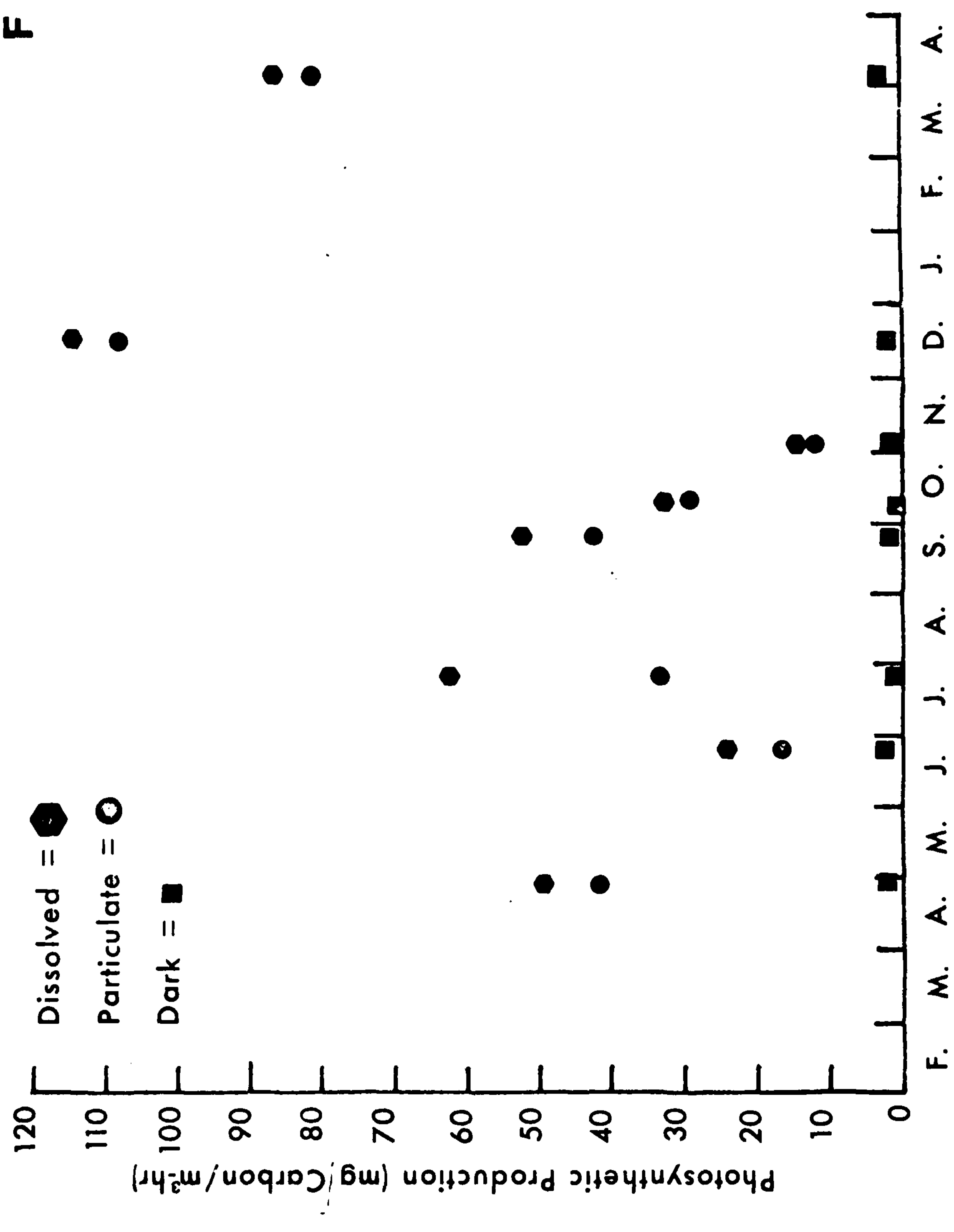


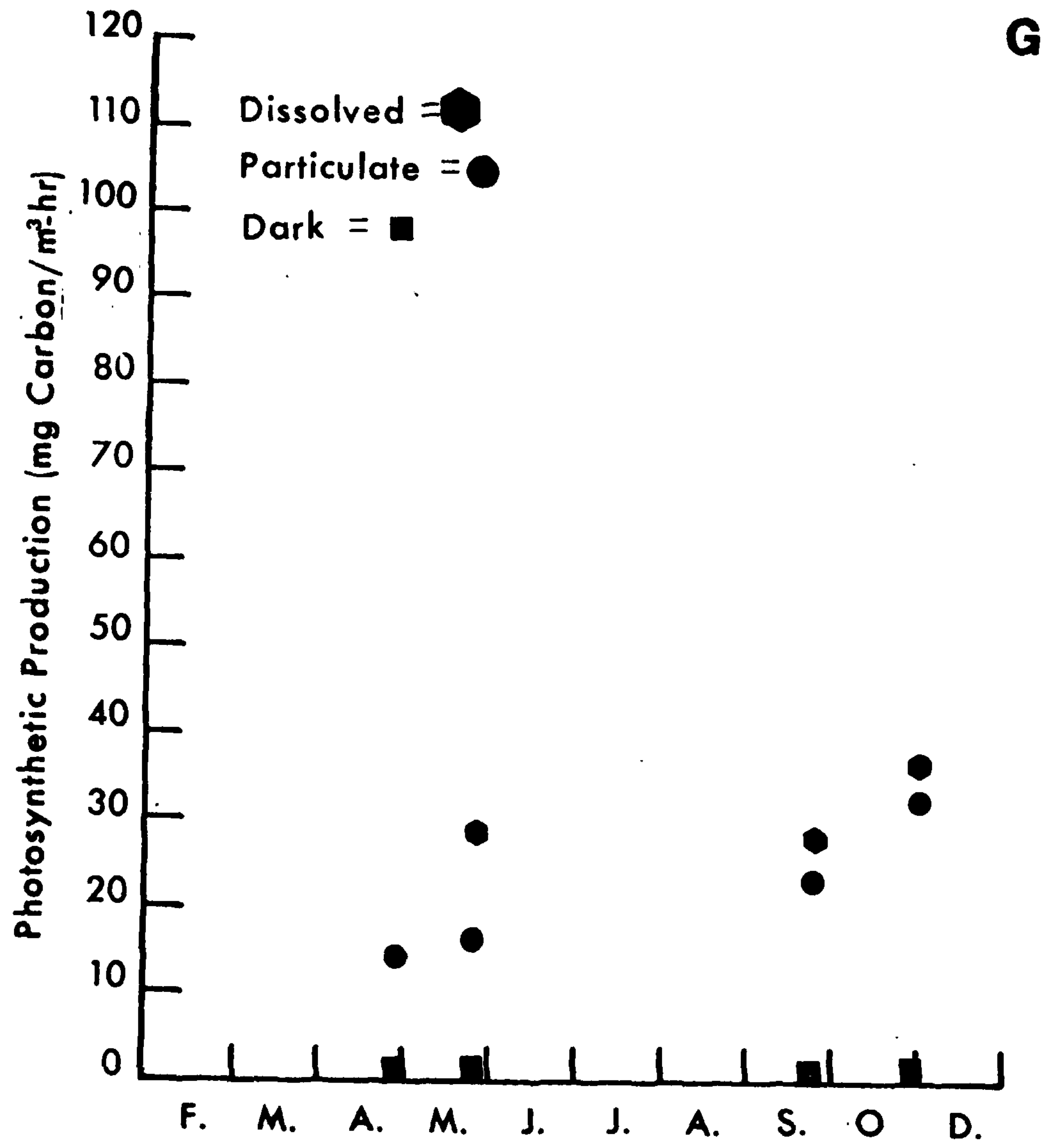
Photosynthetic Production (mg Carbon/m³-hr)
120
110
100
90
80
70
60
50
40
30
20
10
0
Dissolved =
Particulate =
Dark =
C
F.
M.
A.
M.
J.
J.
A.
S.
O.
N.
D.

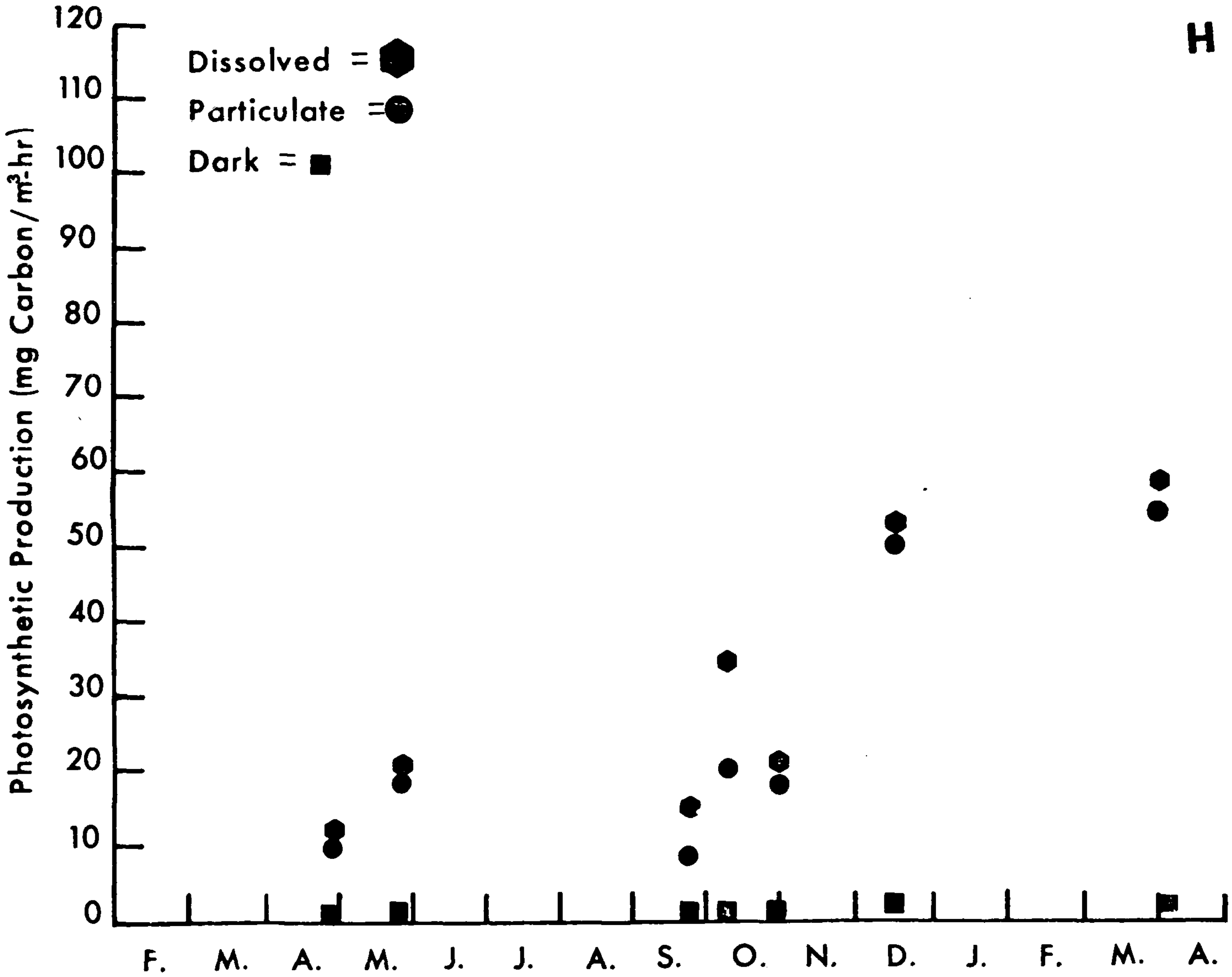

D
Dissolved =
Particulate =
Dark =
Photosynthetic Production (mg Carbon/m³hr)
120
110
100
90
80
70
60
50
40
30
20
10
0
F.
M.
A.
M.
J.
J.
A.
S.
O.
N.
D.
J.
F.
M.
A.



Dissolved =
Particulate =
Dark =
E
Photosynthetic Production (mg Carbon/m³-hr)
120
110
100
90
80
70
60
50
40
30
20
10
0
F.
M.
A.
M.
J.
J.
A.
S.
O.
N.
D.


F
Dissolved =
Particulate =
Dark =
Photosynthetic Production (mg/Carbon/m³-hr)
120
110
100
90
80
70
60
50
40
30
20
10
0
F. M. A. M. J. J. A. S. O. N. D. J. F. M. A.


G
Dissolved =
Particulate =
Dark =
Photosynthetic Production (mg Carbon/m²hr)
120
110
100
90
80
70
60
50
40
30
20
10
0
F.
M.
A.
M.
J.
J.
A.
S.
O
D.


H
Dissolved =
Particulate =
Dark =
Photosynthetic Production (mg Carbon/m³-hr)
120
110
100
90
80
70
60
50
40
30
20
10
0
F.
M.
A.
M.
J.
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O.
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D.
J.
F.
M.
A.

Chapter 8

THE DISTRIBUTION AND ABUNDANCE OF PLANKTON OF LAKE PONTCHARTRAIN, LOUISIANA, 1978

by

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ABSTRACT

During 1978, plankton taxa of Lake Pontchartrain and its surrounding wetlands were mostly freshwater forms. Phytoplankters were predominately greens (59%), blue-greens (20%), and euglenoids (6%). Microzooplankters were mostly rotifers (70%), copepods (6%), and cladocerans (5%). Macrozooplankters were nauplii and adult *Acartia tonsa* (44%), Cladocera spp. (17%), and decapods (17%).

In terms of abundance, the plankton were dominated by euryhaline and brackish forms. Dominant phytoplankters were diatoms, *Lynbya*, *Cryptomonas*, *Phacotus*, *Ankistrodesmus*, *Anabaena*, *Oscillatoria*, *Microcystis*, and *Chlamydomonas*. Dominant micro- and macrozooplankters were copepod nauplii, *Synchaeta* spp., *Brachionus plicatilis*, *B. angularis*, *Filinia pejleri*, *Texadina sphinctosoma*, *Conochilus* sp., *B. deitersi*, *Keratella cochlearis*, cyclopoid and calanoid juvenile copepods, *Acartia tonsa*, *Chaoborus* sp. (insecta), *Diaptomus* sp., *Eurytemora affinis*, and crab zoea (*Rhithropanopeus harrisii*).

Recurrent group analyses, by the Fager (1957) technique, formed two recurrent groups of phytoplankton, four groups of microzooplankton and three groups of macrozooplankton.

Group I of the phytoplankton was found at all lake and marsh stations, but only during summer (June, July, Aug., Sept.) and fall (Oct., Nov.). The best stations (statistically significant at $P < 0.01$) in terms of abundances were located in the marsh areas, off the southeastern shore near New Orleans, off Pass Manchac, and off South Point. Group II was found mostly (81%) at marsh stations, where its members were significantly more abundant; it occurred mainly during the summer months.

Group I of the microzooplankton was found at all stations, mostly (91%) during summer, but predominately at lake stations (51%). Group II was also found at all stations, mostly during spring (March, April, May) and summer (70%); it is a brackish water association. Group III was found equally at lake and marsh stations but occurred predominately (75%) during winter (Dec., Jan., Feb.); it is a fresh to brackish water association. Group IV was found in the Lacombe marsh area and was freshwater in character.

Group I of the macrozooplankton was found at all stations, mainly during the summer; it is brackish water association. Group II was found at most stations about equally throughout the year; it is also a brackish water association. Group III is a freshwater association that was found mostly during spring and summer months; its "best" stations were located in the marsh areas.

Hydrographic data and the distribution of the recurrent groups suggest that Lake Pontchartrain is a well-mixed system but has a weak west-to-east salinity gradient from low to high. The distribution of

plankton shows that more freshwater forms occurred in the west side of the lake, but at any one time, all taxa can be found throughout the lake. High nutrient and chlorophyll concentrations and high rates of primary production were found in the marshes, off the southeast shore near the city, and near Pass Manchac. These data correlate well with high abundances of phytoplankters at the same locales.

The wetlands surrounding Lake Pontchartrain and selected nearshore environs are being subjected to high nutrient loads. These nutrients are causing a strong response in the plankton and could possibly affect the entire food web of the lake.

INTRODUCTION AND OBJECTIVES

Plankton are an important feature in the food web of Lake Pontchartrain. The phytoplankton use nutrients in the water and become either part of the detritrus storage or are used by zooplankton, selected benthos, and nekton. Similarily, the zooplankton use the phytoplankton as an energy source and they, in turn, are used by selected benthos, or by nekton, or they also become part of the detritrus storage. As a result, plankton can often be used as indicators of hydrologic changes of water masses, of nutrient enrichment, and of changes in the structure of the food web.

The purpose of this study was to determine the distribution and abundance of dominant phytoplankton and zooplankton in Lake Pontchartrain. These data along with other research data will form the basis for assessing the present environmental conditions and quality of the lake and its surrounding wetlands.

MATERIALS AND METHODS

I. Phytoplankton

A variety of methods exist in the literature for determining phytoplankton abundance, and each has advantages and disadvantages (Lund and Talling 1957, Vollenwieder 1974). Among these are the gravimetric techniques, pigment (chlorophyll) extractions, and direct cell counts. This study used direct cell counts, as described below. The primary advantage of direct cell counting is that it permits qualitative (taxonomic analysis) as well as quantitative assessment of the phytoplankton community (Vollenwieder 1974). It is, therefore, possible to determine the relative amount each algal taxon contributes to total phytoplankton production (Vollenwieder 1974). See Lund et al. (1958) and Vollenwieder (1974) for a detailed discussion of the advantages and disadvantages of direct cell counts.

Thirteen stations located in and around Lake Pontchartrain (see Fig. 1) were sampled at monthly intervals from February 1978 to December 1978. Three samples were collected from the water column with a plastic polyvinylchloride (PVC) pipe, 3 cm wide and 42 cm long (Lund 1949). The sample was then emptied into a 3-liter plastic bottle. A 50-ml aliquot was taken from this container (the rest was discarded), treated with Lugol's solution for organism preservation, and then transported to the laboratory. Algal cells were counted in the laboratory using the Utermohl sedimentation technique (Utermohl 1958) and a Leitz inverted microscope.

Detailed laboratory methods are given in Appendix 1.

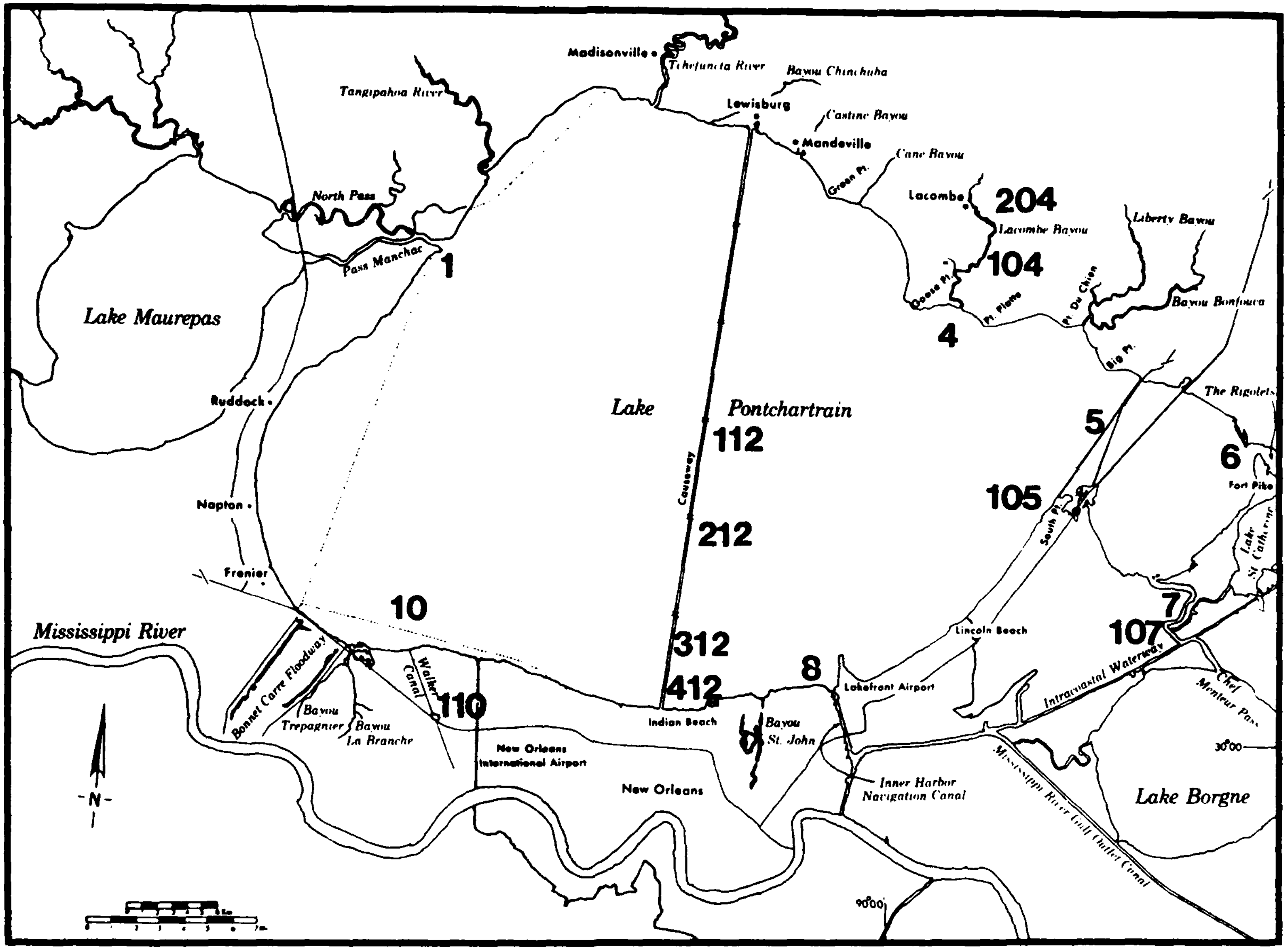

Figure 1. Station locations for plankton sampling in Lake Pontchartrain, LA, during 1978. Stations 1, 10, and 112 are considered West Lake. Stations 4, 5, and 105 are considered East Lake. Stations 212, 312, 412 are considered City. Stations 6, 7, and 8 are considered Pass stations. Stations 105, 204, 107, and 110 are considered Marsh stations.

II. Microzooplankton

Thirteen stations were sampled once monthly from February 1978 until December 1978 (Fig. 1) except in April, when they were sampled twice.

Samples were collected with a net with No. 20 mesh (79 micrometer) and 1/2-meter diameter opening with a length of 2.5 m (5:1 ratio). The No. 20 net was towed at the surface for 30-90 seconds, depending on water turbidity. Tows were made at a speed that allowed the net to remain 2-5 cm below the surface. The net was towed from the bow of the boat, with the boat traveling in reverse. The volume of the water filtered through the net was measured by a calibrated flowmeter (General Oceanics). The flowmeter was mounted in the net's opening approximately one-third of the distance of the diameter from the rim. The following equations were used to calculate distance towed and volume of water filtered.

1) Distance Towed = (No. of rotations of flowmeter) x (.0269 meters traveled per 1 flowmeter revolution).

2) Theoretical volume filtered = (distance towed) (π) (radius of net)^2.

Net samples were washed with clean water into plastic jars and frozen immediately on dry ice, then returned to the lab for processing and analysis.

Detailed laboratory methods are given in Appendix 1.

III. Macrozooplankton

Monthly surface tows were made at each station using a No. 2 (374μ) plankton net; it was 0.5 m in diameter with a length of 2.5 m (5:1 ratio). The duration of the tows ranged between 5-15 minutes,

depending on the amount of suspended material and clogging. Tows were made at a speed that allowed the net to remain 2-5 cm below the surface. The net was towed from the bow of the boat, with the boat traveling in reverse. The volume of the water filtered through the net was measured by a calibrated flowmeter (General Oceanics). The flowmeter was mounted in the net's opening approximately one-third of the distance of the diameter from the rim. The following equations were used to calculate distance towed and volume of water filtered.

1) Distance Towed = (No. of rotations of flowmeter) X (.0269 meters traveled per 1 flowmeter revolution).

2) Theoretical volume filtered = (distance towed) (π) (radius of net)^2.

After each tow, the net was throughly washed down from the outside to force the specimens into the collecting bucket. The bucket was then removed from the net, and the sample was washed, with clean tap water, into a pint size jar. The samples were labeled, placed on dry ice, and then taken back to the lab (within 10 hours of the collecting) where they were frozen.

Detailed laboratory methods are given in Appendix 1.

During the field collections, water temperature was measured by a mercury themometer (°C). Water turbidity was measured with a Secchi disc. Water salinity was measured with a refractometer.

The Fager analysis (1957) was used to identify recurrent groups of plankton taxa and details are given in Appendix 2 along with various statistics used to characterize the plankton populations.

STATION LOCATIONS AND DESCRIPTIONS

Figure 1 shows the location of 16 plankton stations sampled. Three of the stations (212, 312, 412) were added in August and sampled through

December. Twelve stations are located off the major tributaries and in the passes of the lake. Four stations are located in the marsh areas. Salinity and temperature were measured from July through December. Turbidity was measured from February through May. A brief description of each station will be found in Appendix 3.

RESULTS

I. Phytoplankton

A. Taxa, Distributions, and Abundances

Sixty-four phytoplankton taxa were identified from 134 samples. The complete taxa listing is given in Table A41 in the appendix. Table 1 lists nine categories of phytoplankton taxa and two types of habitat characterizations. Greens were the dominant taxa form and comprised 59.4% of the taxa; they were followed by blue-greens and euglenoids that comprised 20.3% and 6.2% of the taxa, respectively. However, this listing does not give a complete picture of taxa diversity of phytoplankton types because the diatoms were not identified as to genus or species. Freshwater types dominated the phytoplankton taxa and comprised 73% of the total.

The composition during each season generally reflected those of the year's data; namely, greens always dominated the species makeup and were followed by blue-greens and euglenoids. However, blue-greens were more apparent (relative to the other taxa) during summer and fall, concurrent with an increase of euryhaline forms and diatoms.

Detailed taxa data for each season are given in Appendix 4.

Table 1. Selected Taxa Categories and Characterizations for Phytoplankton of Lake Pontchartrain, Louisiana, During 1978

	Taxa Category and Characterization	Year		Spring (MAM)		Summer (JJAS)		Fall (ON)		Winter (DJF)	
		# Taxa	(%)	# Taxa	(%)	# Taxa	(%)	# Taxa	(%)	# Taxa	(%)
1	Chlorophyta (Greens)	38	(59.4)	24	(60.0)	23	(52.3)	11	(45.8)	18	(58.1)
2	Cyanophyta (Blue-greens)	13	(20.3)	7	(17.5)	10	(22.7)	6	(25.0)	4	(12.9)
3	Euglenophyta (Euglenoids)	4	(6.2)	4	(10.0)	4	(9.1)	3	(12.5)	4	(12.9)
4	Chrysophyta (Yellow-greens)	3	(4.6)	1	(2.5)	2	(4.5)	0	---	0	---
5	Diatoms	2	(3.1)	2	(5.0)	2	(4.5)	2	(8.3)	2	(6.5)
6	Cryptophyta (Cryptomonads)	1	(1.6)	1	(2.5)	1	(2.3)	1	(4.2)	1	(3.2)
7	Pyrrhophyta (Dinoflanellates)	1	(1.6)	1	(2.5)	1	(2.3)	1	(4.2)	1	(3.2)
8	Chloromonadophyta (Chloromonads)	1	(1.6)	0	---	0	---	0	---	1	(3.2)
9	Bulbous filament type	1	(1.6)	0	---	1	(2.3)	0	---	0	---
		64	(100.0)	40	(100.0)	44	(100.0)	24	(100.0)	31	(100.0)
1	Euryhaline	17	(27.0)	14	(35.0)	15	(34.1)	10	(41.7)	12	(38.7)
2	Freshwater	47	(73.0)	26	(65.0)	29	(65.9)	14	(58.3)	19	(61.3)
		64	(100.0)	40	(100.0)	44	(100.0)	24	(100.0)	31	(100.0)

B. Recurrent Groups of Phytoplankton: Distributions, Statistics, and Characterizations

Recurrent groups and associates, formed by Fager analysis (1957), are given in Figure 2 for the phytoplankton of Lake Pontchartrain during 1978. Groups based on all samples of the year are shown in the center of Figure 2, and seasonal groups form the periphery. Selected statistics and characterizations for the taxa of each group during the year are given in Tables 2 and 3. The following descriptions give first the distributions of each group and then selected statistics and characterizations.

Two groups of recurrent phytoplankton taxa were formed from the year's data. Group I is composed of eight taxa with one associate member. Groups II consists of three members and two associates.

Group I was found together in 21 samples taken throughout the year. More than half (62%) of these occurred during the summer months; 38%, during fall. There were no occurrences of this group during spring and winter. Group I was found at all stations at various times during the year, except at The Rigolets (Station 6; see Fig. 1). Almost half of the samples (48%) were from lake stations; 19% were from the passes, and the remaining 33% occurred at the marsh stations. A concordance test (Table 2) was made on the rank of the abundances of the taxa of Group I (within samples) at those stations where they occurred together; it was significant at the 1% level. This indicates that there was significant "agreement" among the taxa in regard to the "best" and "worst" stations; namely, each of the phytoplankton taxa of Group I tended to be most or least abundant at the same stations. The first half of these samples (i.e., 11 out of 21) were predominately from the Lacombe marsh stations. This means these phytoplankters were most abundant as a group in the

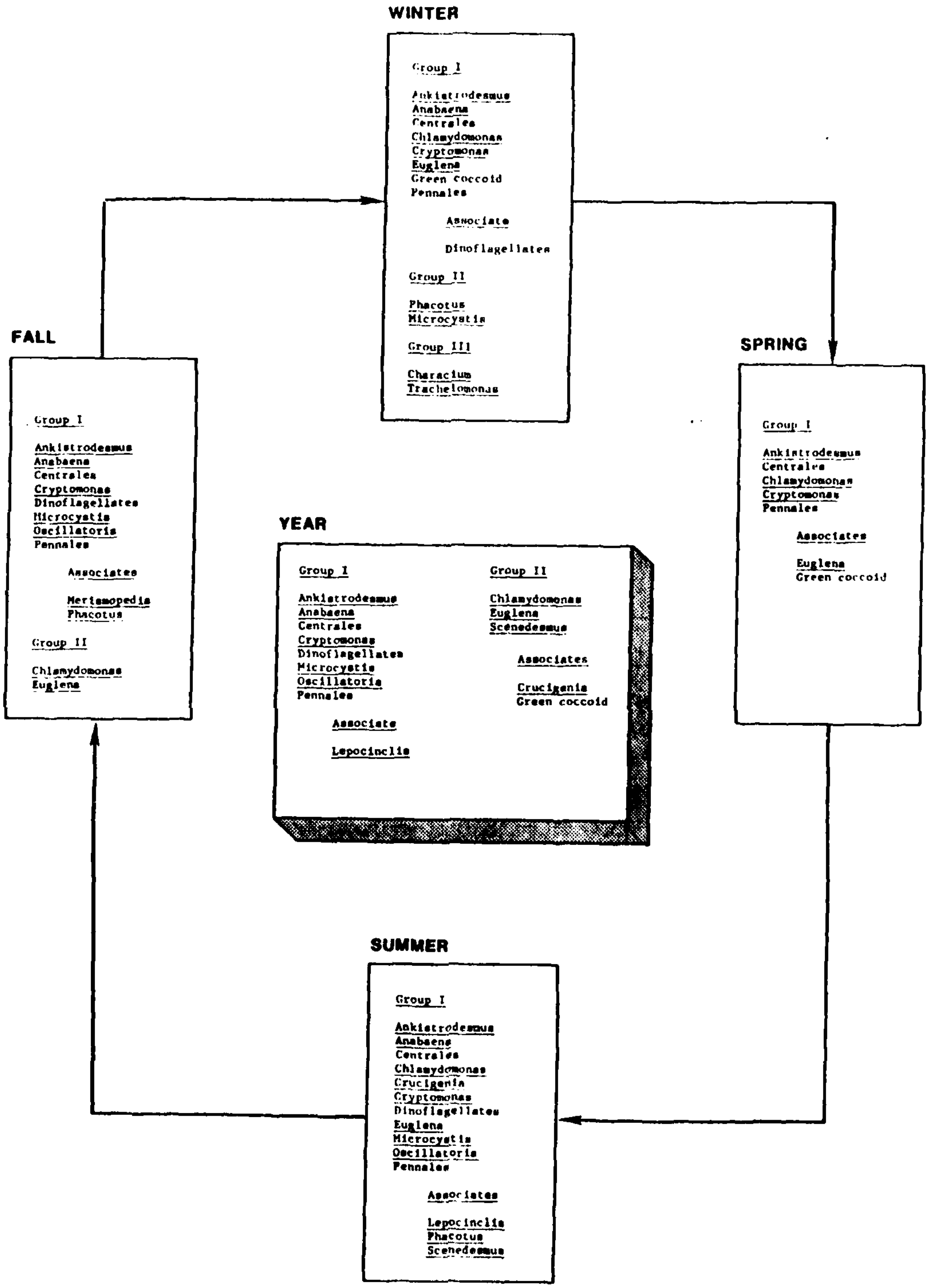

Figure 2. Recurrent groups (Fager 1957) of phytoplankton taxa from Lake Pontchartrain, LA, 1978, by year and by season.

Table 2. Results of Kendall's Coefficient of Concordance (W Test) for Ranking the Abundances of each Phytoplankton Taxa of Recurrent Groups. Ranking was done within Samples (Equivalent to Stations) and within Taxa (See Siegel 1956 or Tate and Clelland 1957)

Year and Group	Ranking Within	
	Taxa	Samples
Year		
Group I	**	**
Group II	**	**
Spring		
Group I	NS	$P < 0.20$
Summer		
Group I	**	**
Fall		
Group I	NS	**
Winter		
Group I	**	NS

**$P < 0.01$.

NS = Not significant.

Lacombe marsh. However, this group of phytoplankters was also abundant along the South Shore near New Orleans (Station 412), at the IHNC (Station 8), and at South Point (Station 105). In addition, a concordance test was made on the abundances within taxa, and it was significant at the 1% level. This indicates that the taxa can be ranked in terms of their overall mean abundance as follows: Centrales > Cryptomonas Ankistrodesmus > Oscillatoria > Microcystis > Pennales > Anabaena > Dinoflagellates.

Selected statistics and characterizations for taxa of Group I and its associate taxon are given in Table 3. All taxa were frequent members of the phytoplankton community; minimum frequency is 30% (40 out of 134) for Lepocinclis. Strong dominance, however, is shown only by centric diatoms (66% of the samples) and to a lesser extent by Cryptomonas (26%), pennate diatoms (16%), Ankistrodesmus (11%), and Anabaena (8%). Mean abundances for Centric diatoms, Cryptomonas, and Ankistrodesmus, over the year, are about one order of magnitude higher than the other taxa, though the standard errors of the means are quite high. All taxa have small k-values and relatively large variance:mean ratios, which may indicate a general pattern of aggregation. Group I and its associate taxon comprise five freshwater and four euryhaline taxa.

Group II is composed of three members and two associates. It was found together in 32 samples and at all stations during various times of the year. A concordance test (Table 2) was made on the rank of the abundances (within samples) of the taxa of Group II at those stations where they occurred together, and it was significant at the 1% level. This indicates significant "agreement" among the three taxa in regard to

Table 3. Selected Statistics for Phytoplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for 1978[†]

Taxa Groups	Frequency[†]	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
GROUP I										
Anabaena	82	11	63	21	9	3	8	0.16	964	FW
Ankistrodesmus	123	15	105	22	4	24	3	0.46	643	FW
Centrales	133	88	394	49	1	236	1	0.79	830	EURY
Cryptomonas	97	35	285	86	2	12	4	0.17	3459	FW
Dinoflagellates	78	4	38	8	10	4	6	0.16	239	EURY
Microcystis	50	9	71	20	7	0	---	0.07	764	FW
Oscillatoria	58	5	93	36	5	0	---	0.08	1818	EURY
Pennales	124	22	65	8	8	27	2	0.54	130	EURY
ASSOCIATE										
Lepocinclis	40	0	5	2	18	0	---	0.08	71	FW
GROUP II										
Chlamydomonas	97	11	76	16	6	10	5	0.22	487	EURY
Euglena	84	1	24	6	12	4	7	0.20	179	EURY
Scenedesmus	54	0	6	2	17	0	---	0.13	66	FW
ASSOCIATES										
Crucigenia	44	0	9	2	13	0	---	0.08	102	FW
Green coccoid	47	1	4	1	21	0	---	0.12	30	EURY

[†]See Materials and Methods, Appendix 1.

the "best" and "worst" stations; namely each phytoplankton taxa of Group II was most or least abundant at the same stations. The first half of these samples (i.e., 16 out of 32 samples) was predominately (81% of the total 32 samples) from marsh stations and, in particular (50% of the total), from the Lacombe marsh area. In addition, a concordance test made on the abundances within species was significant at the 1% level (Table 2). This indicates that the species dominance can be expressed by the sum of their ranks; thus, the mean abundances of Chlamydomonas is generally greater than Euglena, and the abundance of Euglena is, in turn, usually greater than Scenedesmus. Group II occurred mostly during the summer months (63% of the time); it occurred 6%, 19%, and 12%, respectively, during fall, winter, and spring. Many of the occurrences were from Stations 104 and 204 in the Lacombe marsh area.

Selected statistics and characterizations for the taxa of Group II and its associates are given in Table 3. These taxa were frequent members (>33% of samples) of the phytoplankton community, but only Chlamydomonas was dominant (8% of the time). Taxa of Group II show a pattern of aggregation, as indicated by small k-values and large variance:mean ratios. Three taxa of Group II are euryhaline and two taxa are freshwater.

Detailed group data for each season are given in Appendix 4.

II. Microzooplankton

A. Taxa, Distributions, and Abundances

Ninety-six microzooplankton taxa were identified from 139 samples. The complete taxa listing is given in Table A51 in the Appendix. Table 4 lists 14 general taxa categories of microzooplankton and 7 types of

Table 4. Taxa Categories and Characterizations for Microzooplankton from Lake Pontchartrain, LA During 1978

	Taxa Category and Characterization	Year		Spring (MAM)		Summer (JJAS)		Fall (ON)		Winter (DJF)	
		# of Taxa	(%)	# of Taxa	(%)	# of Taxa	(%)	# of Taxa	(%)	# of Taxa	(%)
1	Rotifer	67	(70)	32	(66)	46	(68)	29	(75)	24	(69)
2	Copepod	6	(6)	6	(13)	6	(9)	6	(15)	6	(17)
3	Cladocera	5	(5)	2	(4)	4	(7)	1		3	(9)
4	Insect larvae	3	(3)	1		1		—		1	
5	Nematod	1		—		1		—	(10)	—	(5)
6	Barnacle	1		1		1		1		1	
7	Mollusc	1		1		1		1		—	
8	Polychaete	1	(10)	1	(15)	1	(16)	1		—	
9	Tardigrada	1		1		1		—		—	
10	Decapod	1		1		2		—		—	
11	Isopod	1		—		1		—		—	
12	Mysid	1		—		—		—		—	
13	Ostracoda	1		—		1		—		—	
14	Unknowns	5	(5)	1		1		—		—	
	Total	96	(100)	47	(100)	68	(100)	39	(100)	35	(100)
1	Brackish	6	(8)	5	(13)	5	(9)	4	(12)	5	(17)
2	Fresh	46	(62)	21	(54)	36	(66)	16	(48)	14	(48)
3	Fresh or Brackish	8	(11)	6	(15)	4	(7)	6	(18)	6	(21)
4	Tychoplanktonic*	1	(1)	—	—	1	(2)	—		--	—
5	Fresh Tychoplanktonic	7	(10)	3	(8)	4	(7)	3	(9)	2	(7)
6	Benthic	5	(7)	3	(8)	4	(7)	3	(9)	--	--
7	Benthic Tychoplanktonic	1	(1)	1	(2)	1	(2)	1	(4)	2	(7)
	Total	74	(100)	39	(100)	55	(100)	33	(100)	29	(100)
	Not classified	22		8		13		6		6	
		96		47		68		39		35	

*Tychoplanktonic: Organisms of the benthic community occurring accidently in the plankton.

habitat characterizations. Rotifers were the dominant forms and comprised 70% of the year's taxa list; they were followed by copepods and cladocera, each of which made up 6% and 5% of the year's taxa, respectively. Freshwater types dominated the fauna and comprised 62% of the total. Brackish and fresh-to-brackish forms comprised about 19% of the total.

Taxa during each season showed generally the same general composition: namely, rotifers were the dominant faunistic type, followed by copepods and cladocerans. Freshwater forms were also dominant during each season.

Detailed taxa data are given in Appendix 5.

B. Recurrent Groups of Microzooplankton: Distributions, Statistics, and Characterizations

Recurrent groups and associates formed by Fager analysis (1957) are given in Figure 3 for the microzooplankton of Lake Pontchartrain, Louisiana, during 1978. Groups based on all samples of the year are shown in the center of Figure 3, and seasonal groups form the periphery. Selected statistics and characterizations for the taxa of each group for the year are given in Tables 5 and 6. The following descriptions give first the distributions of each group and then selected statistics and characterizations.

Four groups of recurrent microzooplankton species and taxa were formed from the year's data. All taxa of Group I were present >39% of the time (54 occurrences out of 139 samples for Texadina sphinctosoma). Taxa of Group II and its associates were present at least 30% of the time, and taxa of Group III were present at least 10% of the time. Taxa of Group IV were present only 3% of the time.

Group I was found together in 35 samples; it occurred at all stations at various times of the year. Over half (51%) of these occurrences were

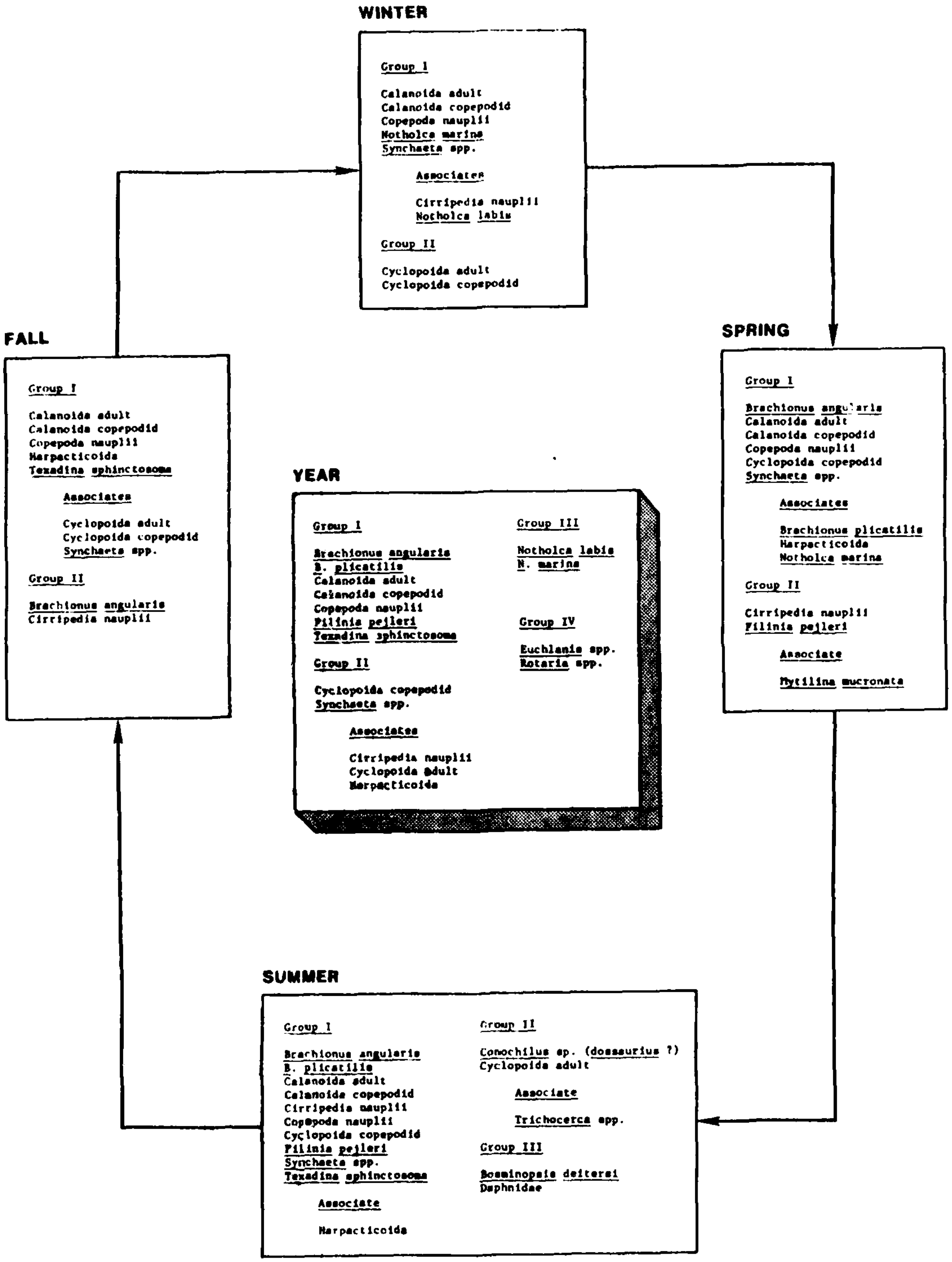

Figure 3. Recurrent groups (Fager 1957) of microzooplankton taxa from Lake Pontchartrain, LA, 1978, by year and by season.

Table 5. Results of Kendall's Coefficient of Concordance (W Test) for Ranking the Abundances of each Taxa of Indicated Recurrent Groups Within Samples (Equivalent to Stations) and Within Taxa (See Siegel 1956 or Tate and Clelland 1957)

Groups	Ranking Within	
	Taxa	Samples
Year		
I	**	**
II	NA	--
III	NA	**
IV	NA	--
Spring		
I	**	--
II	NA	--
Summer		
I	**	**
II	NA	**
III	NA	--
Fall		
I	**	**
II	NA	--
Winter		
I	**	**
II	NA	--

**P < 0.01.

--P > 0.20.

NA = Not applicable.

Table 6. Selected Statistics for Microzooplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for the Year 1978[†]

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
GROUP I										
Brachionus angularis	93	13	88159	30704	4	1920	5	0.08	1.3×10^5	FBW
Brachionus plicatilis	69	8	35051	10347	9	244	7	0.06	3.9×10^5	BW
Calanoida adult	116	10	117261	70179	3	3834	3	0.15	5.3×10^6	--
Calanoida copepodid	126	10	41627	8750	8	9970	2	0.22	2.3×10^5	--
Copepoda nauplii	134	94	216201	41698	1	61416	1	0.25	1.0×10^6	--
Filinia pejleri	60	9	53656	17826	6	0	---	0.04	7.5×10^5	FBW
Texadina sphinctosoma	54	0	5943	1755	15	0	---	0.04	6.6×10^4	Benthic
GROUP II										
Cyclopoida copepodid	85	1	10793	5110	12	272	6	0.08	3.1×10^5	--
Synchaeta spp.	106	32	44216	10354	7	2676	4	0.11	3.1×10^5	BW
ASSOCIATES										
Cirripedia nauplii	66	0	739	177	27	0	---	0.07	5.4×10^3	BW
Cyclopoida adult	42	1	7499	7046	14	0	---	0.03	8.4×10^5	--
Harpacticoida	46	0	893	378	25	0	---	0.04	2.0×10^4	Benthic
GROUP III										
Notholca labis	14	0	106	65	40	0	---	0.01	5.0×10^3	FBW
Notholca marina	29	0	1037	718	24	0	---	0.02	6.3×10^4	BW
GROUP IV										
Euchlanis spp.	4	0	0.49	0.36	86	0	---	0.003	3.3×10^1	FW
Rotaria spp.	4	0	3	2	74	0	---	0.002	2.0×10^2	Benthic

[†]See Materials and Methods section in text.

at lake stations; 29% were in the tidal passes; and 20% were in the marshes. Group I occurred mostly in summer (91%); 3% during the fall and 6% in spring. There were no occurrences of Group I during winter.

A concordance test was made on the rank of the abundances of the taxa of Groups I, II, III, and IV, both in terms of ranking within taxa and within samples or stations (Table 5). For Group I of the year data, there was significant concordance ($P < 0.01$) within taxa. This implies consistency of taxa dominance. The relationship among the taxa can be expressed in terms of mean abundances: Copepoda nauplii > Calanoida adult > *B. angularis* > *F. pejleri* > Calanoida copepodid > *B. plicatilis* > *T. sphinctosoma*. Taxa of Group I significantly ($P < 0.01$) agreed as to the best and worst habitats. There was also significant concordance, within samples, for Group III.

Selected statistics and characterizations for the year's microzooplankton groups are given in Table 6. All taxa of Group I are frequent members of the microzooplankton community; the minimum frequency is 39% (54 out of 139 for *Texadina sphinctosoma*). However, Copepoda nauplii (probably *Acartia tonsa*) dominated all other taxa in terms of abundance; they were dominant in 134 out of 139 samples. Mean and median densities roughly followed the statistics for frequency and dominance in that Copepoda nauplii and Calanoida adult abundance is about one order of magnitude (10^5 inds/m^3 compared to 10^4 inds/m^3) greater than the other taxa. All taxa show small k-values and large variance:mean ratios, which indicate a pattern of aggregation.

Members of Group II were found together in 67 samples. Group II occurred at all stations at various times during the year; it was found

39% of the time at lake stations, 39% at marsh stations, and 22% in the passes. This group occurred 36% of the time during spring; 34% during summer; and, to a lesser extent (12% and 18%, respectively), during fall and winter.

Group III was found together in 12 samples. These samples were found 42% of the time at lake stations, 42% at marsh stations, and 17% in the passes. This group occurred 75% of the time during winter, 17% during spring, and 8% during fall; it was not found during the summer months.

Groups II and its associates and Group III were less frequent components of the microzooplankton than Group I; minimum frequency was 10% (14 out of 139 samples for Notholca labis). Synchaeta spp., however, was a dominate form 76% of the time; the other taxa of these groups were never that strongly dominant. The mean abundances for Synchaeta spp. and Cyclopoida copepodid are also generally larger than the other taxa by 1 to 2 orders of magnitude (10^5 compared to 10^4 and 10^3 inds/m^3). Cyclopoida copepodid and Synchaeta spp. showed an aggregated pattern; Cirripedia nauplii, Cyclopoida adults, and Harpacticoida were less aggregated. (See k-values and variance:mean ratios.) Group II is brackish. Group III is fresh to brackish in character.

Group IV was found together in three samples; all were taken in the Lacombe marsh area. Group IV was not as aggregated as the other taxa.

Detailed group data for each season are given in Appendix 5.

III. Macrozooplankton

A. Taxa, Distributions, and Abundances

Copepods, cladocerans, and decapods dominated the species composition of the macrozooplankton, and there were generally more freshwater than brackish water forms (Table 7).

Twenty-three taxa were identified from 139 samples. The complete taxa listing is given in Table 8.

The macrozooplankton of Lake Pontchartrain during 1978 consisted almost entirely of two major taxa: Copepoda nauplii and *Acartia tonsa* (Table 8). The mean abundance of Copepoda nauplii, the most abundant taxa, was 41,856 inds/100 m^3. The mean abundances of the next most abundant taxa, *Acartia tonsa*, was 27,986 inds/100 m^3. The mean abundances of crab zoea (mostly *Rhithropanopeus harrisii*), *Eurytemora affinis*, *Mesocyclops edax*, *Cladocera* spp., and *Chaoborus* larvae were 707, 990, 517, 368, and 440 inds/100 m^3, respectively. The mean densities of the remaining taxa were always at least one order of magnitude less (Table 8).

Mean density of macrozooplankton peaked in February, with two minor peaks in March and ' ne. The lowest mean density was during November. Mean abundance during February was 404,218 inds/100 m^3; during June, 63,430 inds/100 m^3; and during March it was 10,020 inds/100 m^3. The mean abundance during November was 298 inds/100 m^3 (Table 9).

Copepoda nauplii were most abundant during February, with 227,727 inds/100 m^3. Copepoda nauplii were not collected during September. *A. tonsa* peaked in February with 171,659 inds/100 m^3, an showed a minor peak in December of 9326 inds/100 m^3. *A. tonsa* was collected throughout the year. Cladocera spp. was most abundant during June, 38,435 inds per

Table 7. Generalized Taxa Composition of Macrozooplankton from Lake Pontchartrain, LA, During 1978

		Year		Spring		Summer		Fall		Winter	
		# of Taxa	(%)	# of Taxa	(%)	# of Taxa	(%)	# of Taxa	(%)	# of Taxa	(%)
1	Copepod	10	(44)	7	(50)	8	(57)	7	(70)	8	(67)
2	Cladocera	4	(17)	1	(7)	1	(7)	1	(10)	2	(17)
3	Decapoda	4	(17)	3	(22)	2	(14)	1	(10)	1	(8)
4	Amphipod	1		1		1		1	(10)	—	
5	Isopod	1		1		1	(22)	—		1	(8)
6	Polychaet	1	(22)	—	(21)	1		—		—	
7	Insect	1		—		—		—		—	
8	Insect larvae	1		1		—		—		—	
		23	(100)	14	(100)	14	(100)	10	(100)	12	(100)
1	Freshwater	10	(56)	5	(45)	5	(50)	4	(44)	6	(55)
2	Brackish	8	(44)	6	(55)	5	(50)	5	(56)	5	(45)
		18	(100)	11	(100)	10	(100)	9	(100)	11	(100)

Table 8. Taxa Listing of Macrozooplankton from Lake Pontchartrain, LA, During 1978

	Taxa	Common Name	Character*	Average abundance (100 m^3)	Rank
1.	Harpacticoida spp.	Copepod	BW	10	13
2.	Eurytemora affinis	Copepod	BW	990	3
3.	Acartia tonsa	Copepod	BW	27,986	2
4.	Copepoda nauplii	Copepod	F/BW	41,856	1
5.	Mesocyclops edax	Copepod	FW	517	5
6.	Cyclopoid copepodid	Copepod	FW	30	8
7.	Cyclops vernalis	Copepod	FW	2	16
8.	Amphipoda spp.	Amphipod	--	6	15
9.	Shrimp mysis	Decapod	--	14	12
10.	Calanoida copepodid	Copepod	BW	<1	--
11.	Daphnidae sp.	Cladocera	FW	7	14
12.	Ceriodaphnia sp.	Cladocera	FW	<1	--
13.	Ctenodaphnia sp.	Cladocera	FW	<1	--
14.	Isopoda spp.	Isopod	--	18	11
15.	Crab Zoea (Rhithropanopeus harrisii)	Decapod	BW	707	4
16.	Cladocera spp.	Cladocera	FW	368	7
17.	Chaoborus larvae	Insect larvae	FW	440	6
18.	Crustacean larvae	Decapod	BW	<1	--
19.	Diaptomus sp.	Copepod	FW	25	9
20.	Decapod megalop	Decapod	BW	<1	--
21.	Argulus sp.	Parasitic copepod	--	20	10
22.	Insects	Insect	--	<1	--
23.	Polychaeta	Polychaet	--	<1	--

*Character means habitat preference (BW = Brackish water; FW = Freshwater). Average abundance is individuals per 100 m^3 of water filtered. Rank is where each taxa is rated relative to the other taxa in terms of their mean abundances.

Table 9. Mean Abundances of Macrozooplankton Taxa per 100 m^3 from Lake Pontchartrain, LA, During 1978

	Taxa	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1.	*Harpacticoida* spp.	---	---	15	---	328	79	8	2	6	5	<1
2.	*Eurytemora affinis*	4,674	1,608	20	3	40	18	---	---	4	68	25
3.	*Acartia tonsa*	171,659	2,565	323	23	124	174	857	3	231	97	9,326
4.	Copepoda nauplii	227,727	236	2	34	2,562	147	245	---	224	24	114
5.	*Mesocyclops edax*	4	2,136	765	48	3,387	71	36	5	2	---	9
6.	Cyclopoid copepodid	---	4	---	---	---	---	5	---	---	---	---
7.	*Cyclops vernalis*	19	---	---	---	---	---	---	---	---	---	---
8.	Amphipoda spp.	---	13	19	---	---	---	14	4	---	---	---
9.	Shrimp mysis	---	4	27	20	---	---	85	9	---	---	---
10.	Calanoida copepodid	<1	<1	---	---	---	---	---	---	---	---	---
11.	*Daphnidae* sp.	69	---	---	---	---	---	---	---	---	---	---
12.	*Ceriodaphnia* sp.	---	---	---	---	<1	<1	---	---	---	---	---
13.	*Ctenodaphnia* sp.	---	---	---	<1	---	---	---	---	---	---	---
14.	Isopoda spp.	27	---	---	5	---	---	4	75	1	43	17
15.	Crab Zoea (*R. harrisii*)	31	17	1,111	2,284	6,314	1,653	1,298	981	30	---	---
16.	Cladocera spp.	4	1,155	314	35	38,435	433	266	7	14	16	18
17.	Chaoborus larvea	---	2,283	---	---	---	---	---	---	---	---	---
18.	Crustacean larvae	---	<1	---	---	---	---	---	---	---	---	---
19.	*Diaptomus* sp.	4	---	---	---	11,818	124	17	---	---	3	---
20.	Decapod megalop	---	---	---	3	---	---	20	---	---	---	---
21.	*Argulus* sp.	---	---	---	34	371	33	59	18	24	6	2
22.	Insecta	---	---	---	73	51	---	11	9	21	37	5
23.	Polychaeta	---	---	---	---	---	---	---	1	---	---	---
	Total	404,218	10,020	2,595	2,562	63,420	2,732	2,925	1,115	557	298	9,518

100 m^3, and was also collected throughout the year. Crab zoea showed population peaks during the spring and summer months and were not present during November and December. Diaptomus sp. was evident mostly during the summer months, especially June (11,818 inds/100 m^3) and only very sparsely during winter (3 to 4 inds/100 m^3). Eurytemora affinis was most abundant during February (4674 inds/100 m^3) and March (1608 inds/100 m^3). Mesocyclops edax was most abundant during spring and early summer; the fall and winter mean abundances were one to two orders smaller. Chaoborus larvae were found only during March and in rather high densities (i.e., 2283 inds/100 m^3; Table 9).

Mean densities of macrozooplankters for the seasons were greatest during the winter, especially in the passes (Table 10). During the winter, the tidal pass stations had the greatest mean abundances (i.e., $\sim 8 \times 10^5$ inds/100 m^3). Mean abundances in the marshes were highest during summer. Fall abundances were lowest at all lake stations.

Detailed taxa data for each season are given in Appendix 6.

B. Recurrent Groups of Macrozooplankton: Distributions, Statistics, and Characterizations

Recurrent groups and associates formed by the Fager analysis (1963) are given in Figure 4 for the macrozooplankton of Lake Pontchartrain during 1978. Groups based on all samples of the year are shown in the center of Figure 4 and seasonal groups form the periphery. Selected statistics and characterizations of the taxa for the year are given in Tables 11, 12, and 13. The following descriptions give first the distribution of the groups and then selected statistics and characterizations.

Three recurrent groups of macrozooplankton were formed from the year's data. Group I (Argulus sp. and crab zoea, Rhithropanopeus harrisii),

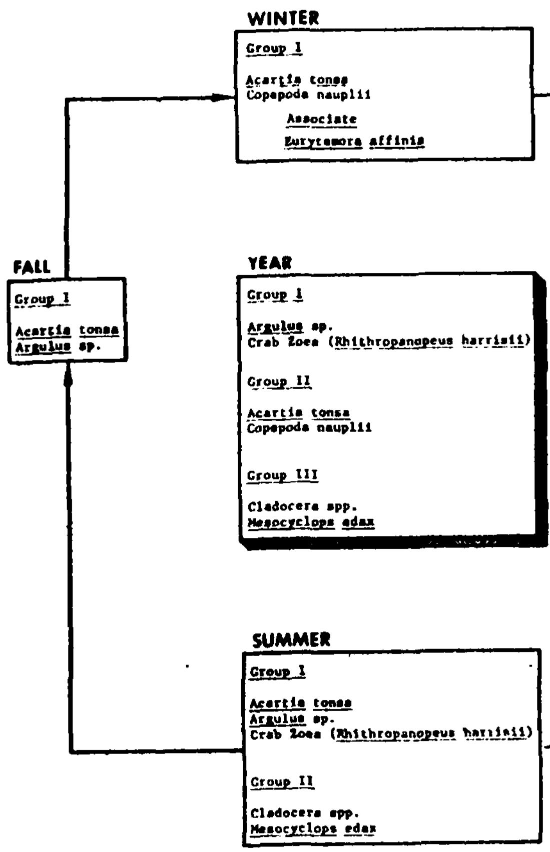

Figure 4. Recurrent groups (Fager 1957) of macrozooplankton taxa from Lake Pontchartrain, LA, 1978, by year and by season.

Table 10. Average Abundances of Macrozooplankton Taxa per 100 m^3 by Lake Section and Season from Lake Pontchartrain, LA During 1978

Season	City	Lake	Marshes	Passes	Average
Spring	---	4,799	18,259	2,450	18,503
Summer	341	3,595	35,874	1,393	10,301
Fall	455	45	362	283	286
Winter	465	32,672	20,970	802,698	214,201
Average	420	10,278	18,866	201,706	

Table 11. Results of Spearman's Rank Coefficient Analysis for Macroplankton. Ranking was on the Abundances of Each Taxa of Indicated Recurrent Group Within Samples;* (Equivalent to Stations)

Group	Ranking Within Samples
Year	
Group I	†
Group II	§
Group III	§
Spring	
Group I	†
Group II	¶
Summer	
Group I	†
Group II	†
Fall	
Group I	†
Winter	
Group I	§

*Ranking within species was not applicable.

†Not significant.

§ $P < 0.05$.

¶ $P < 0.01$.

Table 12. Frequency, Mean (per 100 m^3), and Median (per 100 m^3) for the Recurrent Groups for 1978 in Lake Pontchartrain, LA, by Season†

Taxa Groups	Frequency				Mean				Median			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Group I												
Argulus sp.	4	5	41	12	2	3	40	16	0	0	32	0
Crab Zoea (*Rhithropanopeus harrisii*)	1	26	53	9	16	1201	1128	17	0	80	270	0
Group II												
Acartia tonsa	21	29	31	23	147600	2525	238	177	3366	64	16	38
Copepod nauplii	13	10	17	10	225400	222	100	139	24	0	0	0
Group III												
Cladocera spp.	5	13	23	9	20	1210	276	16	0	0	0	0
Mesocyclops edax	3	14	11	2	8	2415	36	1	0	18	0	0

†See Materials and Methods section in text.

Table 13. Selected Statistics for Macrozooplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for 1978†

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/Mean	Character
Group I										
Argulus sp.	62	8	0.21	0.04	10	0	—	UND*	1.02	
Crab Zoeae (*Rhithropanopeus harrisii*)	89	57	7.07	1.59	4	0.58	1	0.28	47.76	BW
Group II										
Acartia tonsa	104	51	280	201	2	0.54	2	0.24	19577	BW
Copepod nauplii	50	15	419	396	1	0	—	0.05	50563	BW
Group III										
Cladocera spp.	50	11	3.68	1.49	7	0	—	0.13	81.07	FB
Mesocyclops edax	30	6	5.17	2.16	5	0	—	0.06	121.94	FW

†See Materials and Methods section in text.

*Undefined.

Group II (Acartia tonsa and Copepoda nauplii), and Group III (Cladocera spp. and Mesocyclops edax) each consisted of 2 taxa (Fig. 4).

Group I was found together in 52 samples during the year. This group was found at all stations during various times of the year. Over half (78%) of these occurrences was during the summer; 12%, during fall; and 10%, during spring. In addition, more than half of the samples (56%) were found at lake stations (S1, S4, S5, S105, S10, S12, S212, S312, and S412, see Fig. 1), but Group I was also found 25% of the time in the marsh areas (S104, S204, S107, and S110) and 19% of the time in the tidal passes (S6, S7, and S8). A Spearman rank correlation (Table 11) was made on the rank of the abundances within samples of the taxa of Group I and it was not significant, which indicates that there is no agreement as to the "best" and "worst" stations.

Selected statistics and characterizations for Group I are given in Tables 12 and 13. The taxa of Group I, namely Argulus sp. and crab zoea (mostly Rhithropanopeus harrisii), are brackish water forms. Crab zoea have the highest frequency of occurrences; it was present in 89 (64%) of a total of 139 samples analyzed; Argulus sp. was present 45%. Crab zoea dominated 41% of the samples; Argulus sp. dominated 6%. Mean abundance for crab zoea was one order of magnitude greater than Argulus sp.; however, the standard error of the means are high. Crab zoea showed aggregation since it's k-value was $<10^1$. Argulus sp. and crab zoea each showed much seasonal variability in their abundances; however, they were generally more frequent during summer. Argulus sp. was most abundant during the summer months; the highest mean density for crab zoea occurred during the spring and summer.

Group II was found together in 42 samples during the year, 29% of which occurred during winter and summer; 21%, during spring and fall. Group II was found 55% of the time at lake stations; 31%, at the tidal passes; and 14%, at the marsh stations. A Spearman rank correlation showed the taxa abundances within samples was significant ($P < 0.01$), which indicates taxa agreement as to the "best" and "worst" stations.

The taxa of Group II, A. tonsa and Copepoda nauplii, are brackish water forms; they showed a frequency of occurrence of 75% and 36%, respectively. A. tonsa dominated 37% of the samples; Copepoda nauplii dominated 11% of the samples. Both taxa were most abundant during the winter months. Their k-values and variance:mean ratios (Copepoda nauplii and A. tonsa $k < 10^0$, variance:mean ratio $> 10^4$) indicate aggregation of the populations of both taxa.

Group III was found together in 23 samples during the year, of which 9% occurred during the winter; 35%, during the spring; 48%, during the summer; and 8%, during the fall. Approximately 74% of the samples were from marsh stations; the remaining 26% of the samples were from lake stations. There were no occurrences in the tidal passes. A Spearman rank correlation on the rank of the taxa abundances within samples was significant at $P < 0.01$, which indicates agreement among the taxa as to "best" and "worst" stations. Most of the "best" stations were located in the marsh areas; the remaining were in the lake.

The taxa of Group III, Cladocera spp. and Mesocyclops edax, are mainly freshwater forms; they showed a frequency of occurrence of 36% and 22%, respectively. Cladocera spp. dominated 8% of the samples, and M. edax dominated 4%. Both taxa were more abundant during spring.

Cladocera spp. occurred more frequently during the summer; however, _M. edax_ was more evident during spring. Their k-values (Cladocera spp. $k < 10^0$, _M. edax_ $< 10^0$) indicate possible aggregation of the populations of both taxa.

Detailed group data for each season are given in Appendix 6.

DISCUSSION

I. Environmental Background of Lake Pontchartrain Environs

A. Hydrographic Conditions

The major elements of the circulation of Lake Pontchartrain are winds, tides, and rivers (Gael 1979, Stone 1962, and Swenson, Chapter 4). Winds usually dominate over tidal and riverine influences, but periodic discharges via the Bonnet Carre Floodway can contribute as much energy as winds (Gael, Chapter 3). Swenson, Chapter 4, estimates that winds >9 m/sec are sufficient to stir and mix bottom sediments throughout the water column and that winds of that magnitude occur at least 15% of the time. Swenson also found Lake Pontchartrain is well-mixed and does not show a strong two-layered current system nor a pronounced temperature difference (usually <2° C) between the western and eastern halves of the lake. However, the western half is generally fresher ($\lesssim 2$ mmhos/cm) than the eastern half. Nonetheless, tidal exchanges usually dominate the freshwater input and are almost 12 times greater.

Winds over Lake Pontchartrain come predominately (Stone 1972) out of the east, mostly from the northeast during late fall and winter and mostly from the southeast during summer months. Under winds out of the northeast, the circulation of the lake is characterized by large gyrals

in its center and a longshore drift toward the west. Under winds out of the southeast, the general circulation pattern is very similar to winter conditions but current velocities are reduced (Gael, Chapter 3).

The water level of Lake Pontchartrain is controlled by tides and winds. The wetlands surrounding the lake are usually flooded during spring and late fall, and it is estimated that they are flooded at least 50% of time, primarily as the result of winds and storms (Swenson, Chapter 4).

B. Water Temperatures and Salinities

Mean water temperatures of Lake Pontchartrain during 1978 ranged between 5.7°C in February and 30.0°C in August. The greatest temperature range occurred during February, between 7.8 and 20.0°C.

Mean salinities ranged between 0.7°/₀₀ during February and 4.2°/₀₀ in October. The most saline months were September, October, and November, when rainfall and runoff were at their minimum (Table 14).

The east side of the lake was more saline than the west side during 1978. Mean salinity of the east side was 3.5°/₀₀ (the mean salinity of New Orleans stations was 3.7°/₀₀) compared to 2.7°/₀₀ for the west side. The marshes surrounding Lake Pontchartrain tend to be slightly fresher (1.6-2.3°/₀₀) than the lake stations (2.8°/₀₀); the tidal pass stations tend to be the most saline (3.9°/₀₀). It should be noted that the station at the Chef Menteur marsh (S107) is located nearer the incoming saline waters than are the other marsh stations (Table 15).

C. Water Nutrients and Carbon Chemistry

Thirteen chemical variables were measured at lake stations by Stoessell, Chapter 6: water pH, ammonia (NH^{+4}), nitrates (NO^{-3}), dissolved

Table 14. Monthly Mean Salinity, Salinity Range, Mean Temperature, and Temperature Range for Lake Pontchartrain, LA, During 1978

Month	$\bar{X}$ Salinity	Range	$\bar{X}$ Temperature	Range
FEB	.7	0.0-3.2	5.7	7.8-20.0
MAR	1.2	0.1-2.7	12.1	10.0-21.5
APR	1.8	0.0-4.2	21.9	19.0-26.5
MAY	1.9	0.0-4.6	24.1	21.5-28.0
JUN	2.7	0.0-5.2	29.0	28.0-33.8
JUL	3.0	0.0-5.0	28.6	27.5-32.0
AUG	2.6	0.2-4.4	30.0	26.0-32.0
SEP	3.0	0.2-6.7	27.7	27.0-30.0
OCT	4.2	0.8-6.0	22.6	20.0-26.3
NOV	3.6	0.0-8.7	15.6	21.0-25.0
DEC	2.1	0.0-5.5	11.6	8.2-14.0

Table 15. Mean Salinity, Salinity Range, Mean Temperature, and Temperature Range for All Stations in Lake Pontchartrain, LA, During 1978

Station No.	$\bar{X}$ Salinity	Range	$\bar{X}$ Temperature	Range
West Lake				
1	1.7	0-4.0	21.3	6-32.0
10	2.7	2-3.0	24.0	13-31.0
112	3.2	2-5.0	23.7	13-31.0
	(2.5)		(23.0)	
East Lake				
4	2.2	0-4.0	21.2	10-29.0
5	3.8	3-6.0	21.3	9-30.0
105	3.5	3-5.0	23.4	10-29.0
	(3.2)		(22.0)	
City				
212	3.7	3-5.0	22.4	13-30.0
312	3.7	3-4.0	22.0	17-30.0
412	2.7	2-3.0	23.7	17-30.0
	(3.4)		(22.7)	
Marshes				
104	1.2	0-3.0	21.5	6-29.0
204	1.0	0-3.0	23.1	7-29.0
110	2.7	0-4.0	28.0	12 32.0
107	4.4	3-6.0	26.0	16-30.0
	(2.3)		(24.6)	
Passes				
6	4.3	2-6.0	20.0	5-30.0
7	4.2	3-8.0	20.4	11-29.0
8	3.2	3-4.0	25.6	17-30.0
	(3.9)		(22.0)	

organic nitrogen (DON), undissolved organic nitrogen (PON), phosphate (PO_4^{3-}), total dissolved phosphorus (TDP), total organic phosphorus (TOP), silica (Si), dissolved organic carbon (DOC), undissolved organic carbon (POC), and total inorganic carbon (TIC), and chlorophyll (Chloro). Monthly mean values of each of these chemical variables during 1978 in Lake Pontchartrain are given in Table 16.

Highest concentrations of ammonia (NH^{+4}) were found during November, December, and March. Similarly, nitrates (NO^{-3}) were highest during December and March, though a secondary peak was present during May. Phosphates (PO_4^{-3}) were also generally highest during fall, winter, and early spring.

Particulate carbon was highest during March, while chlorophyll concentrations were highest during April.

Nutrient concentrations in the marsh area were significantly higher in the Walker Canal marsh area (near S110) than in the other marsh areas (S104, S204, and near S107; Table 41). However, the mean concentrations of nutrients (N and P) in the marshes are at least one order of magnitude (and sometimes two orders) greater than in the lake (cf. Tables 16 and 17).

D. Chlorophyll Standing Crop and Primary Production

Chlorophyll standing crop and primary production measurements were taken at selected stations in Lake Pontchartrain by Dow and Turner (Chapter 7); the location of many of these stations coincided with those of the plankton stations.

Highest values of chlorophyll (Table 18) were generally found off the Bonnabel and Elmwood Canals of New Orleans, along the south shore of Lake Pontchartrain, and just off the entrance to the Inner Harbor Navigation Canal (IHNC).

Table 16. Monthly Chemical Data from Lake Pontchartrain, LA, for 1978 (Stoessell, Chapter 6)

Month	Temp °C	pH	ug-at/1 NH^{+4}	NO^{-3}	DON[1]	PON[2]	PO_4^{3-}	TDP[3]	TOP[4]	SI[5]	DOC[6]	POC[7]	TIC[8]	CHLOR (g/1)
FEB	9.8	6.95						1.85	.85	54.38	.18	.10	.65	.64
MAR	17.3	8.01	6.70	11.69	28.00	7.89	1.48	1.08	1.81	57.41	1.78	.90	.59	
APR	22.1	7.99	2.63	1.15	23.21	13.66	.71	.72	1.25	29.93	.43	.22	.99	1.36
MAY	27.3	8.11	2.95	4.80	18.29	6.03	.36	.63	.71	50.71	.53	.26		.84
JUN	29.5	7.85	5.78	1.90	22.97	8.02	1.09	1.33	.83	21.46	.63	.19	.70	
JUL	30.4	7.97	4.12	1.74	21.74	8.93	.67	1.02	.70	26.65	.81	.05	.58	
SEP	29.3	7.85	.85	3.53	20.79	5.85	1.38	1.65	.74	47.22			1.31	
OCT	22.6	7.83	1.91	2.55	23.87	7.16	.94	1.03	.81	52.18	45.00		.70	.49
NOV	22.8	8.44	4.67	2.28	22.64	6.79	1.77	2.00	.43	40.33			1.08	
DEC	12.9	7.55	2.83	8.97	25.63	3.54	1.01	1.27	.69	47.50			.65	
WHOLE YEAR	23.7	7.92	3.27	3.73	22.59	7.06	1.00	1.21	.90	46.43	1.57	.42	.85	.74

[1] Dissolved Organic Nitrogen.

[2] Undissolved Organic Nitrogen.

[3] Total Dissolved Phosphorous.

[4] Total Organic Phosphorous.

[5] Silica.

[6] Dissolved Organic Carbon.

[7] Undissolved Organic Carbon.

[8] Total Inorganic Carbon.

Table 17. Average Annual Nutrient Concentrations During 1978 in the Four Marsh Study Sites (mg/l) Surrounding Lake Pontchartrain, LA. (Cramer and Day, Chapter 9)

Study area	NH_4^+-N	$(NO_3^-+NO_2^-)$-N	Dissolved organic -N	Total dissolved -N	Organic -N	Total -N	PO_4^{-3}-P	Total -P	DOC	TOC
Goose Point	0.03	0.04	0.39	0.44	0.62	0.69	0.01	0.06	8.3	10.0
Irish Bayou	0.06	0.02	0.35	0.39	0.62	0.65	0.01	0.04	6.9	8.9
New Orleans East	0.08	0.06	1.64	1.71	1.87	1.94	0.09	0.16	19.7	21.0
Walker Canal	0.10	0.26	0.72	0.87	0.96	1.20	0.14	0.24	10.3	12.1
$\bar{x}$ mg^{-1}	0.0675	0.095		0.852		1.120	0.0625	0.125		
$\bar{x}$ μg^{-1}	67.5	95.0		85.2		1112.0	62.5	125.0		

Table 18. Chlorophyll μg/l (or ppb) from Lake Pontchartrain, LA 1978 (Extracted and Modified from Chapter 7, Dow and Turner)

	(8 + 412) City	(112) Mid Lake	W-E Riverine		(6 + 7) Passes	$\bar{x}$	Median
Spring (MAM)	21.4	(14.3)	(10.2)	(10.6)	(13.6)	14.0	13.6
Summer (JJAS)	15.1	9.9	8.9	(10.7)	8.2	10.6	9.9
Fall (ON)	9.8	8.1	6.2	7.7	8.4	8.0	8.1
Winter (DJF)	9.5	4.1	4.4	5.2	3.0	5.2	4.4
$\bar{x}$	14.0	9.1	7.4	8.6	8.3	(9.5)	8.6
Median =			8.0				

	Spring			Summer				Fall	Winter	
	March	April	May	June	July	Aug	Sept	Oct	Dec	Feb
West Lake										
(area of) 1	5.8	--	7.6	10.4	7.7	11.4	--	6.1	2.2	4.7
Tchefuncte River	15.0	8.2	(5.9)	14.0	6.8	4.3	9.6	5.0	4.9	4.8
(area of) 10	23.1	--	5.5	12.1	--	4.0	--	7.4	4.5	5.3
		(10.2)			(8.9)			(6.2)	(4.4)	
Mid Lake										
112	19.7	7.9	15.4	12.0	6.0	11.7	9.9	8.1	2.9	5.3
		(14.3)			(9.9)			(8.1)	(4.1)	
City										
412	24.7	45.5	13.4	14.9	9.5	23.6	17.7	12.5	8.2	12.2
8	--	11.1	12.2	--	10.7	14.1	--	7.0	8.0	--
		(21.4)			(15.1)			(9.8)	(9.5)	
East Lake										
4	--	--	6.6	--	15.0	8.9	--	8.1	6.7	--
105	--	--	14.7	--	--	8.2	--	7.3	3.7	--
5										
		(10.6)			(10.7)			(7.7)	(5.2)	
Passes										
6	--	--	13.6	--	--	7.0	8.5	7.1	3.7	--
7	--	--	--	--	--	9.0	--	9.8	2.3	--
		(13.6)			(8.2)			(8.4)	(3.0)	

Note: There were no data for November or January.

The yearly mean of chlorophyll was 9.5 μg 1, with spring and summer means of 14.0 μg 1 and 10.6 μg 1, respectively, and a winter mean of 5.2 μg 1. Those stations (called city stations in Table 18) located near the southeast shore of Lake Pontchartrain exhibited the highest mean chlorophyll value of 14.0 μg 1. However, higher than mean concentrations were also evident, on occasion, in mid lake (S112 with 19.7 μg 1), off river discharge locations (such as the Tchefuncte River, Pass Manchac (S1), near Walker Canal (S10), off Bayou Lacombe (S4), and near the tidal passes (S6, The Rigolets).

Primary productivity was also measured by means of the C_{14} technique at selected stations and times in Lake Pontchartrain during 1978 (Dow and Turner, Chapter 7). Mean values by stations, months, and seasons are given in Table 19.

The yearly productivity mean was 31.6 mg•C•m. Spring and summer showed the highest mean rates, with values of 58.5 and 42.3 mg•C•m, respectively. City stations had the high mean rate of 37.6 mg•C•m. However, higher than yearly mean rates were also evident during fall at mid lake (S112) and during winter off Bayou Lacombe (S4), near east Lake Pontchartrain (S5 and S105), and off the tidal passes (S6 and S7).

Assimilation ratios based on productivity rates divided by chlorophyll standing crop values are given in Table 20. High values are taken to mean that the phytoplankton have a high photosynthetic ability and low values, to mean low photosynthetic ability.

The yearly mean ratio was 4:1; winter showed the highest mean of 8.7. City stations had a high mean of 7.2 during winter, but Bayou Lacombe (S4) and east lake (S5 and S105) also had high assimilation

Table 19. Primary Production Values (mg C/m^3) for Lake Pontchartrain, LA, 1978 (Extracted and Modified from Chapter 7, Dow and Turner)

	(8 + 412) City	(112) Mid Lake	W-E Riverine		(6 + 7) Passes	$\bar{x}$	Median
Spring (MAM)	23.5	20.0	18.4	30.7	(58.5)	30.2	30.7
Summer (JJAS)	(33.2)	16.8	22.2	--	9.0	20.3	19.5
Fall (ON)	25.5	(40.5)	21.7	10.0	16.8	28.6	21.7
Winter (DJF)	(68.4)	(33.6)	11.0	(60.3)	(42.3)	(43.1)	42.3
$\bar{x}$	37.6	36.9	18.3	33.7	31.6	31.6	33.7
			26.0				
Median =	29.4	26.8	20.1	30.7	29.5		
			21.7				

	Spring			Summer				Fall	Winter	
	March	April	May	June	July	Aug	Sept	Oct	Dec	Feb
West Lake										
(area of) 1	15.7				9.2			25.1	10.1	2.8
Tchefuncte River	15.0				23.8		26.9	20.5	24.0	
(area of) 1.0								16.3	21.2	
		(18.4)			(22.2)			(21.7)	(11.0)	
Mid Lake										
112	25.6	12.6			16.8		6.9	40.5	23.8	
		(20.0)			(16.8)			(40.5)	(33.6)	
City										
412	32.1				37.1	26.2		32.5	41.0	
8		31.1	23.2					17.5	75.2	
		(23.5)			(33.2)			(25.5)	(68.4)	
East Lake										
4								11.3	71.7	
105								8.8	90.5	
5										
		(30.7)						(10.0)	(60.3)	
Passes										
6							9.4	19.2	47.4	
7								12.7	35.2	
		(58.5)			(9.0)			(16.8)	(42.3)	

Note: There were no data for November or January.

Table 20. Chlorophyll ug/l (or ppb) from Lake Pontchartrain, LA,1978 (Extracted and Modified from Chapter 7, Dow and Turner)

	(8 + 412) City	(112) Mid Lake	W-E Riverine		(6 + 7) Passes	$\bar{x}$	Median
Spring (MAM)	1.1	1.4	1.8	2.9	4.3	2.3	1.8
Summer (JJAS)	2.2	1.7	2.5	--	1.1	1.9	1.9
Fall (ON)	2.6	(5.0)	3.5	1.3	2.0	3.6	2.6
Winter (DJF)	(7.2)	(8.2)	2.5	(11.6)	(14.1)	8.7	(8.2)
$\bar{x}$	3.3	4.1	2.6.	5.3	5.4	4.1	4.1
			3.9				

Median =

	Spring			Summer				Fall	Winter	
	March	April	May	June	July	Aug	Sept	Oct	Dec	Feb
West Lake										
(area of) 1	2.7				1.2			4.1	4.6	0.6
Tchefuncte River	1.0				3.5		2.8	4.1	4.9	
(area of) 10								2.2	4.7	
		(1.8)			(2.5)			(3.5)	(2.5)	
Mid Lake										
112	1.3	1.6			2.8		0.7	5.0	8.2	
		(1.4)			(1.7)			(5.0)	(8.2)	
City										
412	1.3						2.2	2.6	5.0	
8		2.8	1.9		3.9	0.6		2.5	9.4	
		(1.1)			(2.2)			(2.6)	(7.2)	
East Lake										
4		4.2						1.4	10.7	
105		1.7						1.2	12.4	
5								(1.3)	(11.6)	
		(2.9)								
Passes										
6		2.3					1.1	2.7	12.8	
7		6.3						1.3	15.3	
		(4.3)					(1.1)	(2.0)	(14.1)	

Note: There were no data for November or January.

ratios during December, with values of 10.7 and 12.4, respectively. Tidal pass stations also showed high assimilation ratios during winter, with a mean of 14.1.

E. Other Plankton Studies of Lake Pontchartrain

1. Gillespie (Tarver and Savoie 1976)

Gillespie analyzed 265 zooplankton samples taken, usually twice monthly, between 1972 and 1974. The samples were collected just below the surface for about 10 minutes by means of a 1/2-meter Clarke Bumpus net with a No. 2 mesh size (374 microns) and a flow meter. Selected physical and chemical parameters were also measured.

The dominant organism was *Acartia tonsa*, which made up from 32% to 98% of the collections at 7 stations. Mean concentration of *A. tonsa* was 38 inds/100 m^3. The lowest abundance of 21 inds/100 m^3 was found off the southeast shore, near New Orleans (near S412), and the highest concentration occurred near the east lake (S5 and S105).

Other dominant organisms included decapoda larvae, rotifers, cladocerans, and other unknown copepods. The greatest species diversity was evident off the Tchefuncte River and off Pass Manchac (near S1); it was probably the result of the mixture of freshwater plankton associations with brackish forms.

Oyster larvae were found sporatically at most of the stations, including the most westernly and freshwater location, in Lake Maurepas, which probably indicates a water mass that is extremely well mixed.

Gillespie population peaks of zooplankton were evident during all seasons but especially during winter (January and February), although

secondary peaks were present during late spring (April), summer, and fall. However, artifacts due to the sampling schedule and gear type, may obscure the true circumstances.

2. Stern and Stern (1969)

Stern and Stern studied plankton off the southeast shore of Lake Pontchartrain, primarily off the discharge canal of the city, during a 9-month study from November 1968 to July 1969. Plankton was generally collected by towing a net with 406 meshes per inch at 2 knots for 2 minutes though apparently water bottles samples were filtered for plankton. The data were expressed in terms of number individuals per 100 organisms counted. Selected physical and chemical parameters were also measured.

Thirty-seven phytoplankton and 36 zooplankton taxa were identified. The dominant phytoplankters were *Coscinodiscus*, *Sphaerocystis*, and *Chaetoceros*; the zooplankton was dominated by *Acartia tonsa* (adults and nauplii), Tintinnida (protozoan ciliates), and rotifers (principally *Brachionus calyciflorus* and *Keratella valga*).

Phytoplankters were more diverse and were apparently more abundant off the Bonnabel station (near S412 of this study). These data seem to correlate with concentrations of nutrients, especially NO_3, NH^{-4}, and phosphates (see Table 21).

F. Regression Models

Various regression models were constructed to estimate the relationship among selected environmental variables and plankton abundances. The basic form of the models was:

Table 21. Regression Models Constructed for Plankton Data of Lake Pontchartrain, LA, During 1978. Significance Level $P < 0.001$

#	Variables	R^2
	A. Phytoplankton Regression Models	
1	NO_3^-	0.47
2	$NO_3^- + pH$	0.78
4	$(°/_{\circ\circ} \cdot PO_4^{3-}) + pH + NO_3^- + TDP^*$	0.90
4	$(°/_{\circ\circ} \cdot PO_4^{3-}) + Si + pH + TDP$	0.98
5	$(°C)^2 + (°/_{\circ\circ} \cdot PO_4^{3-}) + Si + pH + TDP$	0.99
	B. Additional Phytoplankton Models	
1	$(°/_{\circ\circ} \cdot PON^{\dagger})$	0.55
2	$(°/_{\circ\circ} \cdot PON) + pH$	0.86
4	$(°/_{\circ\circ} \cdot PON) + pH + (\text{Total Zoo}^{\S}) + (PO_4^{-3})$	0.98
5	$(°/_{\circ\circ} \cdot PON) + pH + (\text{Total Zoo}) + (PO_4^{-3})$	0.99
	C. Micro- and Macrozooplankton Regression Models	
1	Si	0.51
2	$(Si \cdot °C) + (°C)^2$	0.71
4	$\text{Phyto} + (°/_{\circ\circ} \cdot TDP) + (°C \cdot °/_{\circ\circ}) + (Si \cdot °C)$	0.99

*TDP = total dissolved phosphorous.

†PON = undissolved organic nitrogen.

§Zoo = total micro- and macrozooplankton.

$$Y = AX_1 + BX_2 + CX_3 \;\ldots\; NH_n$$

where Y = the dependent variable and $X_1 \ldots X_n$ = the independent variables. A stepwise procedure which maximizes R^2 (the Coefficient of Determination) was used according to Barr et al. (1979). This procedure avoids fortitious relationships more than the straight forward procedure. Table 21 gives selected significant results of these analyses.

Phytoplankton regression models in Table 21 are based on Y = individual phytoplankters/ml[1] as a function of 1 and up to 5 independent variables. Inorganic phosphates can account for 47% of the variance in the data, and when combined with pH, for 78% of the variance of the data. If an interaction between salinity and phosphates is added, plus total dissolved phosphates, plus silica, plus a temperature effect, then 99% of the variance of the data can be significantly accounted for. However, other phytoplankton models are possible (as illustrated in Table 21); such as a 5-variable model using an interaction between salinity and particulate organic nitrogen, pH, total macrozooplankton, total zooplankton, and phosphates, which accounted for 99% of the data.

Similar models were constructed micro- and macrozooplankton combined; selected results are given in Table 21. The first model, using silica as the independent variable, can account for 51% of the data. The second model accounts for 71% of the data by using two variables: an interaction between silica and temperature, plus temperature squared. A third model accounts for 99% of the data by using 4 variables: total phytoplankton/ml[1], plus an interaction between salinity and total dissolved phosphates, plus an interaction between temperature and salinity, plus an interaction between silica and temperature.

There are several important features of the data of Table 21. For example, they illustrate the relationships and the importance of selected environmental variables for the number of plankters per unit of water volume. It is not surprising that nutrients (such as nitrogen and phosphorus), silica, temperature, salinity, and the numbers of zooplankton should be closely tied to the abundances of phytoplankton. It is especially interesting, however, that certain of these physical and chemical parameters are also strongly related to zooplankton.

II. Salient Features of Lake Pontchartrain Plankton During 1978

In terms of species composition, freshwater forms dominated the plankton of Lake Pontchartrain during 1978. For example, 73% of the phytoplankters and 62% of the microzooplankters were freshwater forms. However, species abundances were dominated by euryhaline-to-brackish forms, particularly centric and pennate diatoms, *Oscillatoria*, *Cryptomonas*, *Anabaena*, *Chlamydomonas*, *Acartia tonsa*, *Brachionus angularis*, and *B. plicatilis*.

Phytoplankton was primarily made up of greens (59%) and blue-greens (20%) and, to a lesser extent, euglenoids (6%). During spring, marsh stations generally had a more diverse species composition than the lake stations; for example, during spring, marsh stations had 32 phytoplankton taxa compared to 25 for lake stations. Group I of phytoplankton taxa was made up about equally of freshwater and euryhaline forms, and the group was found together 43% of the total sampling at lake stations and 33% of the total sampling at marsh stations. Group I occurred primarily during summer (62%) and fall (38%). Group II was strongly restricted (81%) to the marshes and it occurred primarily (63%) during the summer.

The microzooplankton was dominated by rotifers (70%), copepods (6%), and cladocerans (5%). Freshwater forms (62%) dominated brackish forms (19%). However, copepods generally were more abundant, by an order of magnitude, than the rotifers, particularly nauplii stages. Group I of the microzooplankton was widely distributed; it was found 51% of the total at lake stations, 20% at marsh stations, and 29% in the tidal passes. It occurred primarily (91%) during summer and was not present during the winter. Group II occurred about equally during spring (39%) and summer (34%) and was also equally distributed among the stations; it was found to be 39% of the total at lake stations, 39% at marsh stations, and 22% at the tidal passes. Group III was primarily a spring phenomenon (75%), but it was widespread: it was found to be 42% of the total at lake stations, 42% at marsh stations, and 17% at tidal passes.

Macrozooplankton taxa were dominated by copepods (44%), cladocerans (17%), and decapods (17%). Rank of abundances showed this same pattern of dominance. Group I of the macrozooplankton was a brackish association and was found mainly (78%) during the summer. Though it was widely distributed, it was primarily a lake association (56%). Group II, a brackish association, was also a lake association (55%) but occurred about equally during each season. Group III was a freshwater association and was highly restricted (74% of the total) to marsh stations.

III. Plankton as Environmental Indicators

Plankton collected from Lake Pontchartrain and its surrounding wetlands during 1978 indicate various environmental conditions. First, the plankton indicate some of the features of the general circulation of

the lake. Second, the plankton corroborate the general salinity pattern of a west-to-east gradient. Third, the abundances of phytoplankton suggest nutrient enrichment at selected areas. Fourth, the plankton substantiate some of the environmental findings of previous researchers. Each of these points is discussed in detail below.

Lake Pontchartrain can be generally be characterized as well mixed (Swenson, Chapter 4). This was indicated by the temperature and salinity patterns, and the distribution of phytoplankton taxa generally corroborated this environmental feature. For example, no phytoplankton taxa were strongly restricted to any part of the lake. For example, euryhaline forms of phytoplankton were distributed almost equally between the western (12 taxa) and eastern (13 taxa) half of the lake (Table 22); indeed, more freshwater forms were found in the east or saline half. The distribution of the brackish forms of microzooplankton taxa in the western (14 taxa) and eastern (12 taxa) halves of the lake is about the same. This distribution presumably indicates a circulation mechanism that keeps the lake well mixed. Brackish forms of macrozooplankton taxa are also roughly equally distributed between the halves of the lake. If the lake were not well mixed, then it would be expected that the distribution of brackish forms would be more highly restricted to the eastern, or more saline, half of the lake. In addition, the distribution of each plankton type does not generally show a restriction to a specific lake region. (Some of these groups were, however, more restricted to marsh areas.) For example, Groups I and II of the year's data on phytoplankton were found at all lake stations. Likewise, Groups I, II, and III of the years microzooplankton and macrozooplankton were found at all lake stations.

Table 22. Distribution of Plankton Taxa in Lake Pontchartrain, Louisiana, During 1978, in Terms of Freshwater, Euryhaline, and Brackish Forms at Stations in the Western Half (#1, #10, #12) and in Eastern Half (#4, #5, #105) of the Lake (See Figure 1 for Station Locations)

Association Type	Taxa	West Lake	East Lake
	Phytoplankton		
Freshwater		20	25
Euryhaline		12	13
		32	38
	Microzooplankton		
Freshwater		24	15
Brackish		14	12
		38	27
	Macrozooplankton		
Freshwater		3	5
Brackish		5	7
		8	12
	Combined Plankton		
Freshwater		20 + 24 + 3 = 47	25 + 15 + 5 = 45
Euryhaline to Brackish		12 + 14 + 5 = 31	13 + 12 + 7 = 32

Even though the above data indicate a relatively well mixed system, a weak west-to-east salinity gradient was found in Lake Pontchartrain, Louisiana, during 1978 (Swenson, Chapter 4). The distribution of some of the plankton taxa also show a weak west-to-east gradient of freshwater forms (Table 22). For example, 47 freshwater taxa were found at eastern stations. The distribution of microzooplankton taxa strongly indicates this gradient because 24 freshwater forms were found in the western half of the lake and only 15 were found in the eastern half. Phytoplankton and macrozooplankton taxa did not corroborate the salinity gradient.

The data of other researchers (Dow and Turner, Chapter 7; Stoessell, Chapter 6; and Cramer and Day, Chapter 7) indicate high concentrations of nutrients and chlorophyll at selected stations. For example, nutrients were significantly higher in the marsh areas than in the lake itself (Chapter 7). Also, high concentrations of nutrients were evident off the southeastern shore of the lake, particularly off the entrance of Seabrook Canal (IHNC) (Chapter 6). In addition, chlorophyll concentrations were considerably higher off the discharge canals of the suburbs of New Orleans, in particular off the Bonnabel and Elmwood Canals; chlorophyll was also, at times, highly concentrated off Pass Manchac and the Tchefuncte River. The abundances of phytoplankters strongly corroborated these findings. For example based on the year's data, taxa of Group I of the phytoplankton agreed in rank of abundances within samples. This means that these phytoplankters were significantly more abundant at marsh stations, off New Orleans (S412), off Seabrook (S8), and off Pass Manchac (S1). These data strongly suggest that the phytoplankton were responding to the presence of nutrients by significantly increasing their numbers.

The data of earlier researchers corroborate this interpretation. For example, Gillespie (in Tarver 1976) found oyster larvae at five of her seven stations: at each of the two stations in the western half of the lake; and, more importantly, at the Lake Maurepas station, which is west of Lake Pontchartrain and is much fresher because Lake Maurepas discharges its water into Pontchartrain. This agrees with our statement that the circulation of Lake Pontchartrain is well mixed. The nutrient data of Stern and Stern (1969), particularly NH_4^-, NO_3^-, and PO_4^{-3}, were about one order of magnitude higher at the Bonnabel discharge canal than at other stations along the southeastern shore of Lake Pontchartrain, which corroborates the findings of Stoessell (Chapter 6) and Dow and Turner (Chapter 7). Stern and Stern also found phytoplankters to be more diverse off the Bonnabel Canal.

Remnant of forest swamp on the northwest border of Lake Pontchartrain

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APPENDIX 1

MATERIALS AND METHODS

Detailed Laboratory Methods for Phytoplankton, Microzooplankton, and Macrozooplankton

PHYTOPLANKTON

An aliquot of known volume was pipetted from the Lugol's treated sample and was placed in a Utermohl settling chamber overnight to allow the algae to settle out. They were counted the following day at 400 magnifications. The density of particulate matter (organisms and detritus) dictated the volume used for an aliquot. Too large of an aliquot resulted in a heavy layer of sediment on the chamber floor, and made it very difficult to distinguish, identify, and count phytoplankton organisms. Conversely, too small an aliquot required a longer time to count because the organisms were so few and widely spaced. In dense samples, 300 units were tabulated, because previous work established for this boundary condition that there was a 95% chance for tallying any taxon that contributed >1% of the sample population (Theriot 1978). A unit is defined as a single cell, clump of cells, or colony. However, in depauperate samples, a maximum of 500 microscope fields were counted because of the time needed to count. Although the same statistical limits cannot be placed on these counts, they do indicate a paucity of organisms in the sample. Raw cell counts were converted to cells per liter of water using the following formula:

$$\text{Cells/liter} = \frac{N\ (1 \times 10^6)}{AFH}$$

where:

N = number of organisms counted

A = area (mm^2) of one microscope field at 400X

F = number of microscope fields observed

H = height (mm) of water column in settling chamber

The constant (1×10^6) was used to convert cubic millimeters to liters

To make a generic checklist of the diatoms, specimens from 25 selected samples representing all possible seasons and habitats were cleaned by incineration and mounted on permanent slides with Hyrax mounting medium (Weber 1971). These specimens were observed and identified as to genus.

MICROZOOPLANKTON

Samples were thawed and split into two portions in a Folsom plankton splitter (McEwen et al. 1954). One portion was refrozen for later organic carbon measurements. A second portion was preserved in 5% formalin and stained with eosin red to facilitate observation of organisms. Samples were counted in a Sedgewick-Rafter chamber and using a compound microscope at 100 or 200 magnification. One milliliter of the sample was thoroughly examined, and all invertebrates were tallied. Rotifers were identified to species, when possible, and other organisms were generally identified to order or family. To compute the number of organisms per cubic meter, the following equation was used:

$$\text{Organisms/m} = \frac{2N\ V_1}{FAC\ V_2}$$

(The factor of 2 is used because the sample was split.)

where:

N = No. of organisms in the subsample

V_1 = Volume of concentrated sample in ML*

V_2 = Volume of subsample (1 ML)

F = Flow meter count

A = Area of net mouth in meters squared

C = Meters traveled per meter count

*Some samples had to be diluted because of high densities of phytoplankton and/or zooplankton and detritus.

MACROZOOPLANKTON

The samples were thawed and then divided by means of a Folsom plankton splitter (McEwen et al. 1954). One-half of each sample was refrozen for biomass analysis by organic carbon determinations (Stoessell, Chapter 6); the other half was preserved with a 10% formalin solution and stained with rose bengal.

The total volume of each one-half sample was measured using a graduated cylinder. The half sample was placed back in the jar, and the lid was closed firmly. The jar was turned upside down several times and shaken gently. The lid was then removed, and 2 to 5 aliquots were taken, using a 2 ml Hensen-Stemple pipette. A total of 4 to 10 ml constituted a subsample and was put into a gridded Petri dish. The total subsample size depended on the density of the zooplankton and detritus present in the sample. The zooplankton in the Petri dish were identified and counted. Each sample was subsampled three times. The Hensen-Stemple pipette was rinsed clear of any organisms that might be present with tap water before each subsampling was made. Identification was by observations in Petri dish under 160 magnification of a stereo-microscope; organisms were usually assigned to genus and species level.

APPENDIX 2

FAGER ANALYSIS AND STATISTICS USED TO CHARACTERIZE THE PLANKTON POPULATIONS

The Fager technique (1957 and 1963) was used to identify recurrent groups of plankton taxa. It is based on the geometeric mean of the proportion of joint occurrences, correct for sample size. It is expressed as follows:

$$\frac{J}{\sqrt{NaNb}} - \frac{1/2}{\sqrt{Nb}} \geq \text{cut off point, } (0.50)$$

where J = the number of joint occurrences of species a and b; Na = the total occurrences of species a; Nb = the total occurrences of species b; species are assigned letters so that $Na \leq Nb$. The value of the cutoff can vary between 0.0 (when all species form one group) and 1.0 (when each species forms a separate group). We have used 0.50; this assumes that 0.50 expresses the central tendency or trend of the data.

Various statistics were used to characterize the plankton populations. The statistics and their definitions are given below.

Frequency: the number of times a taxon was present out of the total samples for particular time period.

Dominance: the number of samples a taxon was part of the first 50% of total numbers in a sample.

Mean: the sum of individual observations divided by the total number of observations.

Standard error of the mean (SE $\bar{X}$): standard deviation divided by square root of the sample size.

Median: the value which expresses the 50% or halfway point of a series of data.

Rank: the value assigned to a observation in relation to the next highest and lowest observations. Highest value equals 1.

K-value: an index of dispersion based on k value of the negative exponent, i.e.,

$$\log \frac{N}{N_o} = k \log \frac{1 + \bar{X}}{K}$$

where N = total number of samples, N_o = number of samples containing no individuals, and $\bar{X}$ = mean (Southwood 1966).

Variance/Mean: another index of dispersion based on population variance

where variance = $\left[\Sigma X^2 - \frac{\Sigma X^2}{N} \Big/ N\text{-}1 \right]$

divided by the mean; if this value equals 1 (or closer to it than for values for other species), then it indicates a pattern of random dispersion of the particular population.

Character: A subjective labeling of each taxon according to habitat it prefers. (This was based on present data and the findings of other researchers.)

APPENDIX 3

STATION LOCATIONS AND DESCRIPTIONS

I. Station 1--Pass Manchac

This station is located about 200 m east of the mouth of Pass Manchac. The water depth was between 2-3 m. Salinity ranged from 0-4‰; mean salinity was 1.1‰. Water temperature ranged from 6-32° C, with a mean value of 21.1° C. Secchi disc depth ranged from 30-60 cm in depth; mean depth was 22 cm. This was an open lake station with no observed vegetation. The bottom was soft silt and mud.

II. Station 4--Offshore Lacombe

Station 4 is located approximately 400 m off the mouth of Bayou Lacombe. The water depth varied between 2-3 m. Salinity ranged between 0-4‰, with a mean of 2.2‰. Water temperature ranged below 10-29° C, with a mean of 21° C. Secchi disc depth ranged between 30-75 cm; mean depth was 47 cm. The bottom consisted of soft mud. This was an open lake station.

III. Station 104--Bayou Lacombe Marsh

This station is located approximately 1.6 km inland from the north shore of Lake Pontchartrain. The water depth was between 0.5-2.1 m. Salinity ranged between 0-3‰, with a mean of 1.2‰. Water temperature ranged between 6-29° C, with a mean of 22.2° C. Secchi disc depth ranged between 35-50 cm, with a mean of 46 cm. The bottom was very soft mud mixed with organic matter.

IV. Station 204--Bayou Lacombe

Station 204 is located approximately 6.4 km inland from the north shore of Lake Pontchartrain. The water depth averaged 0.5-2.5 m. The salinity range was 0-1.5‰, with a mean of 1.0‰. Water temperature

ranged between 5-29° C. Secchi disc depth ranged from 25-55 cm, with a mean of 43 cm. The bottom was very soft mud, mixed with organic matter.

V. Station 5--South Point Trestle

Station 5 is located in Lake Pontchartrain between Big Point and South Point to the east of the railroad bridge. Water depth ranged between 3.0 and 3.6 m. Salinity ranged between 3-6‰, with a mean of 3.2‰. Water temperature ranged between 10-30° C, with a mean of 21.3° C. Secchi disc depth varied between 35-100 cm, with a mean of 53 cm. This was an open lake station with no observed vegetation. The bottom was soft mud.

VI. Station 105--South Point

This station was located on the west side of South Point approximately 100 m from the shore. The water depth ranged between 1-2 m. Salinity ranged from 3-5‰, with a mean of 3.6‰. Water temperature ranged between 22-29° C, with a mean of 26.5° C. Secchi disc depth ranged between 25-100 cm; Secchi disc depth mean was 46 cm. This was an open lake station. The bottom was of soft mud and shells.

VII. Station 6--The Rigolets

The water depth in The Rigolets averaged 6 m. Salinity ranged between 2-6%; mean salinity was 4.3‰. Water temperature ranged between 5-30° C; the mean temperature was 20° C. Secchi disc depth varied between 30-100 cm, with a mean of 57 cm. This was an open lake station with the bottom a mixture of hard and soft mud.

VIII. Station 7--Chef Menteur Pass

This station was located in the pass approximately 400 m away from Lake Pontchartrain. The water depth averaged 6 m. Salinity ranged

between 3-8‰; mean salinity was 4.2‰. The water temperature ranged between 11-29° C, with a mean of 20.4° C. Secchi disc depth ranged between 35-75 cm, with a mean of 58 cm. The bottom consisted of soft mud.

IX. Station 107--Chef Menteur Marsh

This station is located in the Chef Menteur marsh area where it meets Bayou Savage. Water depth varied between 0.5-1 m. Salinity ranged between 3-6‰, with a mean of 4.4‰. Water temperature ranged from 16-30° C, with a mean of 26° C. Secchi disc depth ranged between 25-40 cm; mean Secchi depth was 34 cm. The bottom was a mixture of soft mud and organic matter.

X. Station 8--IHNC

Station 8 is located in Lake Pontchartrain west of the mouth of the Inner Harbor Navigation Canal (IHNC) and approximately 800 m from the south shore. The water depth varied between 6-7.3 m. Salinity ranged between 3-4‰; mean salinity was 3.5‰. Water temperature ranged between 17-30° C; mean temperature was 25.6° C. Secchi disc depth ranged from 15-75 cm; mean Secchi depth was 47 cm. This was an open lake station with a mud bottom.

XI. Station 10--Offshore Walker Canal

This station is located 1.3 km north of the mouth of Walker Canal. The water depth varied between 2-2.5m. Salinity ranged between 2-3‰; mean salinity was 2.7‰. Water temperature ranged between 13-31° C; mean water temperature was 24° C. Secchi disc depth ranged between 33-60 cm; mean Secchi depth was 45 cm. This was an open lake station with a bottom of mud, silt, and sand.

XII. Station 110--Inshore Walker Canal in St. Charles Marsh

Station 110 is located about 400 m inland from the south shore of Lake Pontchartrain, with a water depth ranging between 1.5-2.4 m. Salinity ranged between 0-4‰, with a mean of 2.7‰. Water temperature ranged between 23-32° C; mean temperature was 28° C. Secchi disc depth ranged from 25-60 cm, with a mean of 41 cm. This station was in the main canal and had a bottom of soft mud mixed with peat. Heavy growth of *Ceratophyllum*, *Myriophyllum*, and *Cabomba* were present during the warm winter months.

XIII. Station 112--Mid-lake

This station is located at the 19 km marker off the Lake Pontchartrain Causeway. The water depth was 4.6 m. Salinity ranged between 2-5‰; mean salinity was 3.2‰. Water temperature ranged between 13-31° C; mean temperature was 23.6° C. Secchi disc depth ranged from 49-75 cm, with a mean of 62 cm. The bottom was a mixture of soft mud with *Rangia* shells.

XIV. Station 212--South Shore 3

Station 212 is located at the first fixed bridge on the south end of the Lake Pontchartrain Causeway, about 6.7 km offshore. Water depth was 4.6 m. Salinity ranged between 3-5‰; mean salinity was 3.7‰. Water temperature ranged from 13-30° C; mean temperature was 22.4° C. This was an open lake station where the bottom was soft mud with *Rangia* shells.

XV. Station 312--South Shore 2

This station is located approximately 800 m of the south shore on the east side of the Lake Pontchartrain Causeway. The water depth

varied between 2-3 m. Salinity ranged from 3-4‰; mean salinity was 3.7‰. Water temperature ranged from 17-30° C, with a mean value of 23.7° C. This was a shore station with a bottom of soft mud and organic matter.

XVI. Station 412--South Shore 1

Station 412, a shore station, is located 400 m from the south shore, off Indian Beach, on the east side of the Lake Pontchartrain Causeway. Water depth varied between 1-1.8 m. Salinity ranged from 2-3‰; mean salinity was 2.6‰. Water temperature ranged from 17-30° C; mean temperature was 23.7° C. The bottom was soft mud and organic matter.

APPENDIX 4

PHYTOPLANKTON

A. Taxa, Distributions, and Abundance by Season

B. Recurrent Groups by Season: Distributions, Statistics, and Characterizations

Table A41. Phytoplankton Taxa Identified from Stations in Lake Pontchartrain, LA, During 1978

Taxa	Character	Common Name
1. Centrales	EURY	Diatoms
2. Pennales	EURY	Diatoms
3. Dunaliella	EURY	Greens
4. Green coccoid	EURY	Greens
6. Chlamydomonas	EURY	Greens
7. Dysmorphococcus	F.W.	Greens
8. Characium	F.W.	Greens
9. Hydrodictyon	F.W.	Greens
10. Pediastrum	F.W.	Greens
11. Ankistrodesmus	F.W.	Greens
12. Tetraedron	F.W.	Green
13. Crucigenia	F.W.	Greens
14. Scenedesmus	F.W.	Greens
15. Arthrodesmus	F.W.	Greens
16. Cosmarium	F.W.	Greens
17. Euglena	EURY	Euglenoids
18. Eutreptia	EURY	Euglenoids
19. Lepocinclis	F.W.	Euglenoids
20. Trachelomonas	F.W.	Greens
21. Dinoflagellatae	EURY	Dinoflagellates
22. Cryptomonas	F.W.	Cryptomonads
23. Gonyostomum	F.W.	Chloromonad
24. Chroococcus	F.W.	Blue green
25. Oscillatoria	EURY	Blue green
26. Anabaena	F.W.	Blue green
27. Calothrix	EURY	Blue green
28. Eudorina	F.W.	Greens
29. Haematococcus	F.W.	Greens
30. Pandorina	F.W.	Greens
31. Phacotus	EURY	Greens
32. Platymonas	F.W.	Greens
33. Pyramimonas	F.W.	Greens
34. Volvox	F.W.	Greens

Table A41. (Continued)

Taxa	Character	Common Name
35. *Gloeocystis*	F.W.	Greens
36. *Palmella*	F.W.	Greens
37. *Chlorella*	EURY	Greens
38. *Desmatractum*	F.W.	Greens
39. *Lagerheimia*	EURY	Greens
40. *Onychonema*	F.W.	Greens
41. *Phacus*	F.W.	Euglenoids
42. *Heterococcus*	F.W.	Yellow green
43. *Anacystis*	F.W.	Blue green
44. *Merismopedia*	EURY	Blue green
45. *Microcystis*	F.W.	Blue green
46. *Lyngbya*	EURY	Blue green
47. *Spirulina*	EURY	Blue green
48. *Closteriopsis*	F.W.	Greens
49. *Closterium*	F.W.	Greens
51. *Carteria*	F.W.	Greens
52. Colonial flagellate	F.W.	Greens
53. Blue green #1	F.W.	Blue green
55. *Spondylosium*	F.W.	Greens
56. *Dictyosphaerium*	F.W.	Greens
57. *Coelosphaerium*	F.W.	Blue green
58. *Actinastrum*	F.W.	Greens
59. *Oedogonium*	EURY	Greens
60. *Gomphosphaeria*	F.W.	Blue green
61. *Trochiscia*	F.W.	Green
62. *Dinobryon*	F.W.	Yellow green
63. *Staurastrum*	F.W.	Greens
64. *Eucapsis*	F.W.	Blue green
65. *Botrycoccus*	F.W.	Greens
66. *Chrysococcus*	F.W.	Yellow green
67. Bulbous filament	F.W.	

A. Taxa, Distributions, and Abundances by Season

1. Spring

Abridged phytoplankton taxa and abundance categories for spring months (March, April, and May), grouped into lake, passes, and marsh stations, are given in Table 2. Detailed data per taxa per station are given in Table A42.

During the spring of 1978, 40 phytoplankton taxa were identified from 32 samples. Twenty-five taxa were identified from the lake samples; 18 taxa, from the tidal pass samples; and 32 taxa, from the marsh samples (Table A43). Five taxa, *Pediastrum*, *Eutreptia*, *Volvox*, *Spondylosium*, and *Dictyosphaerium*, were found only at lake stations. Twelve taxa were found only at marsh stations: *Dunaliella*, *Eudorina*, *Haematococcus*, *Pandorina*, *Phacotus*, *Chlorella*, *Desmatractum*, *Phacus*, *Heterococcus*, *Closteriopsis*, *Closterium*, and *Merismopedia*. The Lacombe marsh station had 24 taxa during spring.

Lyngbya was highly abundant (>10^3 inds/ml) in the IHNC. Centrales, *Cryptomonas*, and *Phacotus* were abundant (<10^3 to >10^2 inds/ml); Centrales was abundant in lake and tidal pass stations; *Cryptomonas* and *Phacotus* were abundant in the marsh stations. Fourteen taxa including 12 new taxa were moderately abundant, and most of these were from marsh stations. Twenty-eight taxa including 20 new taxa were in the average abundance or common category (<10^1 to >1 inds/ml), and they were distributed almost equally among the lake, pass, and marsh stations. Nine taxa including 4 new taxa were rare (1 ind or less/ml). Five of these taxa were found at lake stations; 1 taxa, at a tidal pass station; and 3 taxa, at marsh

Table A42. Abundances of Phytoplankton Taxa ml^{-1} During Spring (March, April, May) of 1978 in Lake Pontchartrain, LA, by Individual Stations

Species	Species Number	Lake Proper: West 1	West 10	Mid 12	Mid 4	East 5	East 105	$\bar{X}$
Centrales	1	53	83	1046	229	120	141	279
Pennales	2	32	2	6	23	7	4	12
Dunaliella	3							
Green coccoid	4	5	<1	18	1	1	3	5
Chlamydomonas	6	8	6	26	2	4	3	8
Dysmorphococcus	7					1		1
Pediastrum	10				2			2
Ankistrodesmus	11	6	4	55	41	21	10	23
Crucigenia	13	6				1		4
Scenedesmus	14		1		2			1
Cosmarium	16	2		4	2	6		4
Euglena	17	2	1		5	1	3	2
Eutreptia	18			26	1			14
Lepocinclis	19	2		4		7		4
Trachelomonas	20		<1					<1
Dinoflagellatae	21		4	4	1		4	3
Cryptomonas	22	10	1	6	6	13	1	6
Chroococcus	24			2				2
Oscillatoria	25			6				6
Anabaena	26			235		2	2	80
Calothrix	27							
Eudorina	28							
Haematococcus	29							
Pandorina	30							
Phacotus	31							
Pyramimonas	33							
Volvox	34		1					1
Chlorella	37							
Desmatractum	38							
Phacus	41							
Heterococcus	42							
Merismopedia	44							
Lyngbya	46			21		5	1	9
Closteriopsis	48							
Closterium	49							
Carteria	51		1					1
Colonial flagellate	52							
Bluegreen #1	53	4						4
Spondylosium	55					3		3
Dictyosphaerium	56			4				4
	$\bar{X}$	12	9	98	26	14	17	

Table A42. (Continued)

Species	Species Number	Passes 6	Passes 7	Passes 8	X̄	Marshes 110	Marshes 107	Marshes 104	Marshes 204	X̄
Centrales	1	355	110	498	321	59	80	77	14	57
Pennales	2	23	6	15	15	179	15	62	44	75
Dunaliella	3								3	3
Green coccoid	4	2		2	2	13	3	3	3	5
Chlamydomonas	6	6	9	47	21	48	6	16	55	31
Dysmorphococcus	7					1				1
Pediastrum	10									
Ankistrodesmus	11	122	27	134	94	163	50	156	15	96
Crucigenia	13	1		1	1	10		6		8
Scenedesmus	14	2		4	3	4		8	4	[illegible]
Cosmarium	16	2			2		48			48
Euglena	17		8	2	5	8		4	30	14
Eutreptia	18									
Lepocinclis	19	6	1		4	8		3	4	5
Trachelomonas	20		1	4	2			11	8	9
Dinoflagellatae	21		2	5	3	28		6		17
Cryptomonas	22	7	3	1	4	301		130	623	351
Chroococcus	24								8	8
Oscillatoria	25							3		3
Anabaena	26						3	5		4
Calothrix	27	2	2		2					
Eudorina	28							1	8	4
Haematococcus	29							1		1
Pandorina	30							3	8	5
Phacotus	31								159	159
Pyramimonas	33		2		2	7		3		5
Volvox	34									
Chlorella	37								16	16
Desmatractum	38						1			1
Phacus	41							3		3
Heterococcus	42							3		3
Merismopedia	44					14	1	21		12
Lyngbya	46	1		4731	2366	28	2	66		32
Closteriopsis	48							2		2
Closterium	49							15		15
Carteria	51	2			2					
Colonial flagellate	52		2		2					
Bluegreen #1	53					10				10
Spondylosium	55									
Dictyosphaerium	56									
	X̄	41	14	454		55	21	25	63	

Table A43. Phytoplankton Abundance Categories, in Number of Individuals per ml, for Stations in the Lake, Passes, and Marshes During Spring (March, April, and May) 1978 in Lake Pontchartrain, LA, Environs

Abundance	Lake	Passes
$10^4 \geq n > 10^3$ Highly Abundant		Lyngbya (46) (1)
$10^3 \geq n > 10^2$ Abundant	Centrales (1) (1)	Centrales (1) (1)
$10^2 \geq n > 10^1$ Moderately Abundant	Pennales (2) Ankistrodesmus (11) Eutreptia (18) Anabaena (26) (4)	Pennales (2) Chlamydomonas (6) Ankistrodesmus (11) (3)
$10^1 \geq n > 10^0$ Common	Green coccoid (4) Chlamydomonas (6) Pediastrum (10) Crucigenia (13) Cosmarium (16) Euglena (17) Lepocinclis (19) Dinoflagellatae (21) Cryptomonas (22) Chroococcus (24) Oscillatoria (25) Lyngbya (46) Bluegreen #1 (53) Spondylosium (55) Dictyosphaerium (56) (15)	Green coccoid (4) Scenedesmus (14) Cosmarium (16) Euglena (17) Lepocinclis (19) Trachelomonas (20) Dinoflagellatae (21) Cryptomonas (22) Calothrix (27) Pyramimonas (33) Carteria (51) Colonial flagellate (52) (12)
$n \leq 10^0$ Rare	Dysmorphococcus (7) Scenedesmus (14) Trachelomonas (20) Volvox (34) Carteria (51) (5)	Crucigenia (13) (1)
Unique Taxa	Pediastrum (10) Eutreptia (18) Volvox (34) Spondylosium (55) Dictyosphaerium (56) (5)	Calothrix (27) Colonial flagellate (52) (2)
Total Taxa	25	18

Table A43. (Continued)

Abundance	Marshes		New Taxa*
$10^4 \geq n > 10^3$ Highly Abundant			1
$10^3 \geq n > 10^2$ Abundant	Cryptomonas (22) Phacotus (31)		3
	(2)		
$10^2 \geq n > 10^1$ Moderately Abundant	Centrales (1) Pennales (2) Chlamydomonas (6) Ankistrodesmus (11) Cosmarium (16) Euglena (17)	Dinoflagellatae (21) Chlorella (37) Lyngbya (46) Merismopedia (44) Closterium (49) Blue green #1 (53)	12
	(12)		
$10^1 \geq n > 10^0$ Common	Dunaliella (3) Green coccoid (4) Crucigenia (13) Scenedesmus (14) Lepocinclis (19) Trachelomonas (20) Chroococcus (24)	Oscillatoria (25) Anabaena (26) Eudorina (28) Pandorina (30) Pyramimonas (33) Phacus (41) Heterococcus (42) Closteriopsis (48)	20
	(15)		
$n \leq 10^0$ Rare	Dysmorphococcus (7) Haematococcus (29) Desmatractum (38)		4
	(3)		
Unique Taxa	Dunaliella (3) Eudorina (28) Haematococcus (29) Pandorina (30) Phacotus (31) Chlorella (37)	Desmatractum (38) Phacus (41) Heterococcus (42) Merismopedia (44) Closteriopsis (48) Closterium (49)	19
	(12)		
Total Taxa	32		(40)

*New taxa not present in previous abundance categories.

stations. Most of those taxa unique to either the lake or marsh stations were generally rare or common in their abundances.

2. Summer

Abridged phytoplankton taxa and abundance categories for summer months (June, July, Aug., and Sept.) are given in Table A44. Detailed data per taxa per station are given in Table A45.

During the summer of 1978, 44 taxa were identified from 52 samples. Thirty-nine taxa were identified from the lake samples; 29 from the tidal pass samples; and 40 from the marsh samples (Table A44). One taxon, Trochiscia, was found only at lake stations. Seven taxa were found only at marsh stations: Arthrodesmus, Pandorina, Chlorella, Onychonema, Spirulina, Oedogonium, and Dinobryon.

Centrales, Cryptomonas, and Lyngbya were abundant (>10^3 inds/ml) off Pass Manchac and offshore of Walker Canal, respectively, Centrales, Ankistrodesmus, Cryptomonas, and a bulbous filament were also abundant (<10^3 to >10^2 inds/ml) in the marsh stations. Centrales was abundant at almost all stations, but Ankistrodesmus was abundant only at marsh stations. Cryptomonas was abundant in both lake and marsh stations. Lyngbya was abundant only at lake stations. A bulbous filament was abundant only at the Bayou Lacombe station. The remaining taxa were either moderately abundant (<10^2 to >10^1 inds/ml) or were common (<10^1 to >10^0 inds/ml); there were 23 taxa including 21 new taxa and 28 taxa including 16 new taxa in each abundance category, respectively. Nine taxa occurred only rarely (1 or less inds/ ml).

3. Fall

Abridged phytoplankton taxa and abundance categories are given in Table A46; detailed data per taxa per station are given in Table A47.

Table A44. Phytoplankton Abundance Categories, in Number of Individuals per ml, for Stations in the Lake, Passes, and Marshes During Summer (June, July, August, and September) 1978 in Lake Pontchartrain, LA, Environs

Abundance	Lake		Passes	
$10^3 \geq n > 10^2$ Abundant	Centrales (1) Cryptomonas (22) Lyngbya (46)		Centrales (1)	
	(3)		(1)	
$10^2 \geq n > 10^1$ Moderately Abundant	Pennales (2) Ankistrodesmus (11) Euglena (17) Trachelomonas (20) Dinoflagellatae (21) Oscillatoria (25) Anabaena (26) Eudorina (28)	Phacotus (31) Volvox (34) Anacystis (43) Merismopedia (44) Microcystis (45) Closterium (49) Coelosphaerium (57) Actinastrum (58)	Pennales (2) Chlamydomonas (6) Ankistrodesmus (11) Crucigenia (13) Dinoflagellatae (21) Cryptomonas (22) Oscillatoria (25)	Anabaena (26) Phacotus (31) Lagerheimia (39) Microcystis (45) Actinastrum (58)
	(16)		(12)	
$10^1 \geq n > 10^0$ Common	Green coccoid (4) Chlamydomonas (6) Crucigenia (13) Scenedesmus (14) Eutreptia (18) Lepocinclis (19)	Chroococcus (24) Palmella (36) Lagerheimia (39) Carteria (51) Gomphosphaeria (60) Trochiscia (61)	Green coccoid (4) Scenedesmus (14) Euglena (17) Eutreptia (18) Lepocinclis (19) Trachelomonas (20) Gloeocystis (35) Anacystis (43)	Merismopedia (44) Lyngbya (46) Coelosphaerium (57) Chrysococcus (66) Bulbous filament (67)
	(12)		(13)	
$n \leq 10^0$ Rare	Pediastrum (10) Cosmarium (16) Gloeocystis (35)	Phacus (41) Chrysococcus (66)	Volvox (34) Phacus (41) Closterium (49)	
	(5)		(3)	
Unique Taxa	Trochiscia (61)			
	(1)		(0)	
Total Taxa	39		29	

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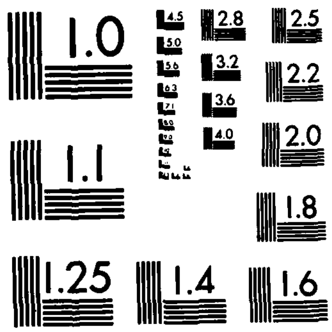

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Table A44. (Continued)

Abundance	Marshes		New Taxa*
$10^3 \geq n > 10^2$ Abundant	Centrales (1) *Ankistrodesmus* (11) *Cryptomonas* (22) Bulbous filament (67)		5
	(4)		
$10^2 \geq n > 10^1$ Moderately Abundant	Pennales (2) *Chlamydomonas* (6) *Crucigenia* (13) *Euglena* (17) Dinoflagellatae (21) *Oscillatoria* (25) *Anabaena* (26) *Pandorina* (30) *Phacotus* (31)	*Chlorella* (37) *Lagerheimia* (39) *Onychonema* (40) *Anacystis* (43) *Merismopedia* (44) *Microcystis* (45) *Coelosphaerium* (57) *Actinastrum* (58)	21
	(17)		
$10^1 \geq n > 10^0$ Common	Green coccoid (4) *Scenedesmus* (14) *Arthrodesmus* (15) *Cosmarium* (16) *Eutreptia* (18) *Lepocinclis* (19) *Trachelomonas* (20) *Eudorina* (28)	*Palmella* (36) *Phacus* (41) *Lyngbya* (46) *Closterium* (49) *Carteria* (51) *Oedogonium* (59) *Gomphosphaeria* (60) *Dinobryon* (62)	16
	(16)		
$n \leq 10^0$ Rare	*Pediastrum* (10) *Chroococcus* (24) *Spirulina* (47)		2
	(3)		
Unique Taxa	*Arthrodesmus* (15) *Pandorina* (30) *Chlorella* (37) *Onychonema* (40)	*Spirulina* (47) *Oedogonium* (59) *Dinobryon* (62)	8
	(7)		
Total Taxa	40		(44)

*New taxa not present in previous abundance categories.

Table A45. Abundances of Phytoplankton Taxa ml^{-1} During Summer (June, July, August, September) of 1978 in Lake Pontchartrain, LA, by Individual Stations

		Lake Proper						
		West		Mid			East	
Species	Species Number	1	10	12	4	5	105	$\bar{X}$
Centrales	1	511	114	72	135	116	106	176
Pennales	2	34	17	8	6	20	17	17
Green coccoid	4		3		2	1	1	2
Chlamydomonas	6	21	13	2	7	3	6	9
Pediastrum	10			1				1
Ankistrodesmus	11	36	43	6	16	10	10	20
Crucigenia	13	8		1	5	5	5	5
Scenedesmus	14	4	10	3	4	2	3	4
Arthrodesmus	15							
Cosmarium	16			1	1			1
Euglena	17	14	41	17	8	1	5	15
Eutreptia	18				2	10	2	4
Lepocinclis	19	2	20	2			1	6
Trachelomonas	20		27					27
Dinoflagellatae	21	7	49	16	4	6	5	15
Cryptomonas	22	1297	258	11	27	8	469	345
Chroococcus	24				6		5	6
Oscillatoria	25	48	52	14	46	27	16	34
Anabaena	26	20	27	89	107	20	43	51
Eudorina	28	1	21					11
Pandorina	30							
Phacotus	31	7	28	7				14
Volvox	34	21			2			11
Gloeocystis	35			1				1
Palmella	36				4	3	1	3
Chlorella	37							
Lagerheimia	39			2	7	21	9	10
Onychonema	40							
Phacus	41		1					1
Anacystis	43	83			1			42
Merismopedia	44	64	30	3	13	10	3	21
Microcystis	45	25	53	41	140	133	174	94
Lyngbya	46	21	1753		1	1	1	355
Spirulina	47							
Closterium	49	21			2	109	16	37
Carteria	51		3					3
Coelosphaerium	57	237	1		26	1	7	54
Actinastrum	58		146	53	7			69
Oedogonium	59							
Gomphosphaeria	60					6		6
Trochiscia	61						3	3
Dinobryon	62							
Chrysococcus	66					1	1	1
Bulbous filament	67							
	$\bar{X}$	118	123	17	23	23	38	

Table A45. (Continued)

Species	Species Number	Passes 6	7	8	x̄	Marshes 110	107	104	204	x̄
Centrales	1	473	229	299	333	346	300	177	105	232
Pennales	2	36	30	9	25	37	40	101	21	50
Green coccoid	4	1		8	5	3		15		9
Chlamydomonas	6	16	10	9	12	19	7	127	242	99
Pediastrum	10					1				1
Ankistrodesmus	11	5	3	51	20	25	2	365	58	112
Crucigenia	13	5		24	14	17	8	14	4	11
Scenedesmus	14	1		4	2	7		18	6	10
Arthrodesmus	15							5		5
Cosmarium	16					4			3	3
Euglena	17	7	2	12	7	48		57	21	42
Eutreptia	18	1	1	6	3		6	5		5
Lepocinclis	19	2		5	3	2	1	17	17	9
Trachelomonas	20			2	2	2		7	17	9
Dinoflagellatae	21	4	3	46	18	97	2	142	88	82
Cryptomonas	22	5	6	40	17	383	1	269	307	240
Chroococcus	24					1				1
Oscillatoria	25	3	3	48	18	63	10	45	6	31
Anabaena	26	11	5	58	25	31	5	18	7	15
Eudorina	28					1		12	14	9
Pandorina	30							23	23	23
Phacotus	31	1		33	17	19		9	34	21
Volvox	34			1	1					
Gloeocystis	35			6	6					
Palmella	36							6		6
Chlorella	37					4		27		16
Lagerheimia	39	5	55		30		56			56
Onychonema	40							14		14
Phacus	41	1		1	1	3		13	12	9
Anacystis	43			3	3	11		14		12
Merismopedia	44		1	9	5	26	5	9	3	11
Microcystis	45	7	17	192	7[illegible]	6	14	275	5	75
Lyngbya	46	16		1	9				3	3
Spirulina	47					1				1
Closterium	49		1		1		9			9
Catteria	51								4	4
Coelosphaerium	57	5	9		7			34		34
Actinastrum	58		1	21	11	23				23
Oedogonium	59								4	4
Gomphosphaeria	60								8	8
Trochiscia	61									
Dinobryon	62							11	9	10
Chrysococcus	66		4		4					
Bulbous filament	67	2			2				161	161
	x̄	29	22	37		45	31	65	45	

Table A46. Phytoplankton Abundance Categories, in Number of Individuals per ml, for Stations in the Lake, Passes, and Marshes During Fall (October and November) 1978 in Lake Pontchartrain, LA, Environs

Abundance	Lake		Passes	
$10^3 \geq n > 10^2$ Abundant	Centrales (1) *Cryptomonas* (22) *Oscillatoria* (25) *Anabaena* (26)			
	(4)			
$10^2 \geq n > 10^1$ Moderately Abundant	Dinoflagellatae (21) *Chroococcus* (24) *Gloeocystis* (35) *Merismopedia* (44) *Microcystis* (45)		Centrales (1) Pennales (2) Dinoflagellatae (21) *Cryptomonas* (22) *Oscillatoria* (25)	
	(5)		(5)	
$10^1 \geq n > 10^0$ Common	Pennales (2) Green coccoid (4) *Chlamydomonas* (6) *Ankistrodesmus* (11) *Scenedesmus* (14)	*Euglena* (17) *Lepocinclis* (19) *Eudorina* (28) *Phacotus* (31)	*Chlamydomonas* (6) *Ankistrodesmus* (11) *Scenedesmus* (14) *Euglena* (17) *Lepocinclis* (19)	*Anabaena* (26) *Phacotus* (31) *Merismopedia* (44) *Microcystis* (45)
	(9)		(9)	
$n \geq 10^0$ Rare	*Lagerheimia* (39)		Green coccoid (4) *Platymonas* (32) *Phacus* (41)	
	(1)		(3)	
Unique Taxa	*Chroococcus* (24) *Eudorina* (28) *Gloeocystis* (35) *Lagerheimia* (39)		*Platymonas* (32)	
	(4)		(1)	
Total Taxa	19		17	

Table A46. (Continued)

Abundance	Marshes		New Taxa[a]
$10^3 \geq n > 10^2$ Abundant	Centrales (1) *Ankistrodesmus* (11) *Cryptomonas* (22)	*Oscillatoria* (25) *Anabaena* (26) *Microcystis* (45)	6
	(6)		
$10^2 \geq n > 10^1$ Moderately Abundant	Pennales (2) *Chlamydomonas* (6) *Crucigenia* (13) *Scenedesmus* (14)	*Euglena* (17) Dinoflagellatae (21) *Phacus* (41) *Anacystis* (43)	11
	(8)		
$10^1 \geq n > 10^0$ Common	Green coccoid (4) *Phacotus* (31) *Merismopedia* (44)		4
	(3)		
$n \geq 10^0$ Rare	*Cosmarium* (16) *Lepocinclis* (19)		3
	(2)		
Unique Taxa	*Crucigenia* (13) *Cosmarium* (16) *Anacystis* (43)		8
	(3)		
Total Taxa	19		(24)

[a] New taxa not present in previous abundance categories.

Table A47. Abundances of Phytoplankton Taxa ml^{-1} During Fall (October, November) of 1978 in Lake Pontchartrain, Lake Pontchartrain, LA, by Individual Stations

		Lake Proper						
		West		Mid		East		
Species	Species Number	1	10	12	4	5	105	$\bar{x}$
Centrales	1		475	60	119	26	52	147
Pennales	2			4	9	15	10	9
Green coccoid	4				2		1	2
Chlamydomonas	6			11		1		6
Ankistrodesmus	11		20	17	2	1	2	9
Crucigenia	13							
Scenedesmus	14				2			2
Cosmarium	16							
Euglena	17				3	1	3	2
Lepocinclis	19		3		3			3
Dinoflagellatae	21		20	19	39	13	6	19
Cryptomonas	22		45	295	185	344	13	176
Chroococcus	24				17			17
Oscillatoria	25		20	752	24	4	45	169
Anabaena	26		18	1308	79	3	119	305
Eudorina	28				2			2
Phacotus	31		18		2	1		7
Platymonas	32							
Gloecystis	35				41			41
Lagerheimia	39						1	1
Phacus	41							
Anacystis	43							
Merismopedia	44		111	34	15		3	41
Microcystis	45		33	72	26		16	37
	$\bar{x}$		76	257	34	41	23	

Table A47. (Continued)

Species	Species Number	Passes 6	7	8	x̄	Marshes 110	107	104	204	x̄
Centrales	1	65	18	120	68	204	30	183	316	183
Pennales	2	30	23	9	21	10	115	37	97	65
Green coccoid	4	1	1		1		2			2
Chlamydomonas	6	1	1	3	2	94	1		93	63
Ankistrodesmus	11	4	2	6	4	10	9	127	705	213
Crucigenia	13							10	112	61
Scenedesmus	14			2	2		1	46	73	40
Cosmarium	16					1				1
Euglena	17		4	8	6	22	6		64	30
Lepocinclis	19	2			2		1			1
Dinoflagellatae	21	48	11	50	36	6	9	42	10	17
Cryptomonas	22	65	71	8	48	105	34	81	690	227
Chroococcus	24									
Oscillatoria	25		1	23	12	1	8	1450	739	550
Anabaena	26	2	2	2	2	1	3	342	173	130
Eudorina	28									
Phacotus	31		1	4	2	3		8	12	8
Platymonas	32			1	1					
Gloeocystis	35									
Lagerheimia	39									
Phacus	41			1	1			14	9	12
Anacystis	43								23	23
Merismopedia	44			5	5	3	1		12	5
Microcystis	45	1	2	4	2	3		681	146	277
	x̄	22	11	17		36	17	252	204	

During fall (Oct. and Nov.) of 1978, 24 taxa were identified from 20 samples. Nineteen taxa were identified from the lake samples; 17, from the tidal pass samples; and 19, from the marsh samples. Four taxa were found only in lake samples: Chroococcus, Eudorina, Gloeocystis, and Lagerheimia. One taxa, Platymonas, was found only in tidal pass samples. Three taxa, Crucigena, Cosmarium, and Anacystis, were restricted to the marsh stations.

Oscillatoria was particularly abundant ($\geq 10^3$ inds/ml) at the Lacombe marsh station (Table A47). Six taxa, Centrales, Ankistrodesmus, Cryptomonas, Oscillatoria, Anabaena, and Microcystis were abundant ($<10^3$ to $\geq 10^2$ inds/ml). Taxon 1, Centrales, was abundant at almost all stations during fall. Ankistrodesmus and Microcystis were abundant only at the Lacombe marsh stations. Cryptomonas, Oscillatoria, and Anabaena were abundant at both lake and marsh stations. Of the remaining taxa, 15 taxa including 11 new taxa were moderately abundant ($<10^2$ to $\geq 10^1$ inds/ml), and 12 taxa including 4 new taxa were common ($<10^1$ to $>10^0$ inds/ml). Six taxa including 3 new taxa occurred only rarely.

4. Winter

Phytoplankton taxa and abridged abundances for the winter (Dec., Jan., and Feb.) of 1978 are given in Table A48; detailed abundance data per taxa per station are given in Table A49.

During winter of 1978, 31 taxa were identified from 30 samples. Twenty-five taxa were identified from the lake samples; 20 taxa, from the tidal pass samples; and 23 taxa, from the marshes. Two taxa, Tetraedron and Closteriopsis, occurred only in marsh samples from the Lacombe area. Four taxa, Dysmorphococcus, Hydrodictyon, Calothrix, and Closterium were

Table A48. Phytoplankton Abundance Categories, in Number of Individuals per ml, for Stations in the Lake, Passes, and Marshes During Winter (December, January, and February) 1978 in Lake Pontchartrain, LA, Environs

Abundance	Lake			Passes		
$10^3 \geq n > 10^2$ Abundant	Cryptomonas (22)		(1)	Centrales (1) Chlamydomonas (6) Cryptomonas (22)		(3)
$10^2 \geq n > 10^1$ Moderately Abundant	Centrales (1) Pennales (2) Chlamydomonas (6) Ankistrodesmus (11)	Euglena (17) Dinoflagellatae (21) Oscillatoria (25)	(7)	Pennales (2) Dunaliella (3) Green coccoid (4) Ankistrodesmus (11)	Euglena (17) Lepocinclis (19) Dinoflagellatae (21)	(7)
$10^1 \geq n > 10^0$ Common	Dunaliella (3) Green coccoid (4) Crucigenia (13) Arthrodesmus (15) Eutreptia (18)	Lepocinclis (19) Phacotus (31) Lagerheimia (39) Microcystis (45)	(9)	Dysmorphococcus (7) Pediastrum (10) Oscillatoria (25) Anabaena (26)	Calothrix (27) Phacotus (31) Lagerheimia (39) Closterium (49)	(8)
$n \leq 10^0$ Rare	Characium (8) Pediastrum (10) Scenedesmus (14) Cosmarium (16)	Trachelomonas (20) Gonyostomum (23) Anabaena (26) Phacus (41)	(8)	Hydrodictyon (9) Scenedesmus (14)		(2)
Unique Taxa	Arthrodesmus (15) Gonyostomum (23)		(2)	Dysmorphococcus (7) Hydrodictyon (9) Calothrix (27) Closterium (49)		(4)
Total Taxa			25			20

Table A48. (Continued)

	Marshes		New Taxa*
$10^3 \geq n > 10^2$ Abundant	Chlamydomonas (6)		3
	(1)		
$10^2 \geq n > 10^1$ Moderately Abundant	Centrales (1) Pennales (2) Ankistrodesmus (11) Dinoflagellatae (21) Cryptomonas (22)		8
	(5)		
$10^1 \geq n > 10^0$ Common	Dunaliella (3) Green coccoid (4) Crucigenia (13) Scenedesmus (14) Euglena (17)	Lepocinclis (19) Oscillatoria (25) Anabaena (26) Phacotus (31) Microcystis (45)	12
	(10)		
$n \leq 10^0$ Rare	Characium (8) Tetraedron (12) Cosmarium (16) Eutreptia (18)	Trachelomonas (20) Phacus (41) Closteriopsis (48)	8
	(7)		
Unique Taxa	Tetraedron (12) Closteriopsis (48)		8
	(2)		(31)
Total Taxa	23		

*New taxa not present in previous abundance categories.

Table A49. Abundances of Phytoplankton Taxa ml^{-1} During Winter (December, January, February) of 1978 in Lake Pontchartrain, LA, by Individual Stations

		Lake Proper						
		West		Mid		East		
Species	Species Number	1	10	12	4	5	105	$\bar{X}$
Centrales	1	52	35	176	44	103	173	97
Pennales	2	69	4		15	9	15	22
Dunaliella	3	3			1			2
Green coccoid	4	4	4		1	5	3	3
Chlamydomonas	6	23	26	30	30	227	105	73
Dysmorphococcus	7							
Characium	8		<1					<1
Hydrodictyon	9							
Pediastrum	10				1			1
Ankistrodesmus	11	15	9	17	20	39	50	25
Tetraedron	12							
Crucigenia	13		2				11	6
Scenedesmus	14	2	<1				1	1
Arthrodesmus	15				2			2
Cosmarium	16	1						1
Euglena	17	27	4	58	1	10	2	17
Eutreptia	18				4			4
Lepocinclis	19		1		15		12	9
Trachelomonas	20		<1					<1
Dinoflagellatae	21			2	75	15	32	31
Cryptomonas	22	57	27	184	17	81	243	101
Gonyostomum	23				1			1
Oscillatoria	25						88	88
Anabaena	26	1	1	2	1			1
Calothrix	27							
Phacotus	31				1		4	2
Lagerheims	39				1	3		2
Phacus	41	1						1
Microcystis	45				4		4	4
Closteriopsis	48							
Closterium	49							
	$\bar{X}$	21	9	67	13	55	53	

Table A49. (Continued)

Species	Species Number	Passes 6	Passes 7	Passes 8	$\bar{X}$	Marshes 110	Marshes 107	Marshes 104	Marshes 204	$\bar{X}$
Centrales	1	373	485	396	418	63	137	100	8	77
Pennales	2	42	59	11	37	109	123	47	4	71
Dunaliella	3	10	224	11	81			7		7
Green coccoid	4	18	20		19	4	27	2	1	8
Chlamydomonas	6	64	267	127	153	41	123	105	160	107
Dysmorphococcus	7		14	4	9					
Characium	8								<1	<1
Hydrodictyon	9	1			1					
Pediastrum	10	3			3					
Ankistrodesmus	11	32	82	19	45	13	29	28	3	18
Tetraedron	12							1		1
Crucigenia	13								2	2
Scenedesmus	14	1			1	2		4	2	3
Arthrodesmus	15									
Cosmarium	16								<1	<1
Euglena	17	11	30		20	5	9	6	<1	5
Eutreptia	18							1		1
Lepocinclis	19	6		90	48			7		7
Trachelomonas	20								<1	<1
Dinoflagellatae	21	11	37		24		33	20	1	18
Cryptomonas	22	78	133		106	98	109	38	27	68
Gonyostomum	23									
Oscillatoria	25	8	7		8	4	6	1	3	3
Anabaena	26	4	4		4	3		2	<1	2
Calothrix	27		5		5					
Phacotus	31		7		7		6			6
Lagerheimia	39		14	6	10					
Phacus	41					1				1
Microcystis	45						6			6
Closteriopsis	48								<1	<1
Closterium	49	9			9					
	$\bar{X}$	42	93	83		31	55	25	13	

found only in samples from the tidal passes. Two taxa, Ankistrodesmus and Gonyostomum, occurred only at lake stations.

Three taxa were abundant ($<10^3$ to $\geq 10^2$ inds/ml): Centrales, Chlamydomonas and Cryptomonas. They were also abundant at most of the other stations. Twelve taxa including 8 new taxa were rare, and they occurred about equally in the lake and marsh stations; however, two rare taxa were found in the tidal passes. The remaining taxa were either moderately abundant or common ($\leq 10^2$ to $>10^0$ inds/ml); there were 11 taxa including 8 new taxa of the moderately abundant taxa, and 17 taxa including 12 new taxa in the remaining common taxa.

B. Recurrent Groups by Season of Phytoplankton: Distributions, Statistics, and Characterizations

1. Spring Groups

The recurrent group for phytoplankton during spring months (March, April, and May) is given in Figure 2. One group was formed. The group (Group 1) is composed of five taxa with two associates.

Group I was found together in 16 samples. A concordance test on abundances was significant at $P < 0.20$ within samples and was not significant within taxa; this indicates weak-to-no agreement among taxa as to the "best" or "worst" stations or the consistency of taxa dominance in terms of their abundances (Table 2).

Selected statistics and characterizations of taxa for the spring group are given in Table A410. Taxa of Group I and its associates were frequent members of the phytoplankton community; all were present in >52% of the spring samples. Ankistrodesmus and Centrales (Centric diatoms) of Group I were dominant 34% and 75%, respectively, during spring; Cryptomonas and Pennales (pennate diatoms) each dominated in 19%

Table A410. Selected Statistics for Phytoplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for Spring (March, May, and June) of 1978[†]

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
GROUP I										
Ankistrodesmus	34	11	118	39	4	27	2	0.39	495	FW
Centrales	37	24	450	133	1	133	1	0.54	1491	EURY
Chlamydomonas	26	1	28	9	6	8	4	0.24	106	EURY
Cryptomonas	21	6	185	110	3	2	5	0.11	2482	FW
Pennales	34	6	61	16	5	16	3	0.46	158	EURY
ASSOCIATES										
Euglena	17	0	8	4	9	0	—	0.15	88	EURY
Green coccoid	19	0	5	2	10	0	—	0.21	24	EURY

[†]See Materials and Methods section in text.

of the samples. Mean abundances of Centric diatoms, Cryptomonas, and Ankistrodesmus are one order larger than the other taxa, but standard errors of the mean are high. Group I comprises predominately euryhaline taxa (3 out of 5), but freshwater forms are evident. The associate group is euryhaline.

2. Summer Groups

There was one recurrent group for phytoplankton during summer months (June, July, August, and September) (Figure 2). Group I is composed of 11 taxa with 3 associates. It was found together in 7 samples. There was significant concordance ($P < 0.01$) among taxa of Group I within stations and taxa, indicating agreement among species as to the "best" and "worst" stations and taxa dominance (Table 2).

Selected statistics and characterizations of the taxa are given in Table A411. The taxa occurred frequently during summer; in >61% of the samples (32 of 52 samples for Crucigenia). Centric diatoms dominated all other forms (35 times out of 52 samples); Cryptomonas was present to a lesser extent (12 of 52); the other taxa rarely dominated the samples (<8 of 52). Mean abundance for Centric diatoms, Cryptomonas, and Microcystis were one order greater than the other taxa. All taxa show a pattern of aggregation (see k-value and variance:mean ratios).

3. Fall Groups

Recurrent groups for phytoplankton during fall months (October and November) are given in Figure 2. Two groups were formed. Group I is composed of eight taxa with two associates. There was no significant concordance among taxa within samples of Group I; this indicates no taxa

Table A411. Selected Statistics for Phytoplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for Summer (June, July, August, and September) of 1978[†]

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
GROUP I										
Anabaena	44	8	64	12	9	34	3	0.36	116	FW
Ankistrodesmus	48	3	95	31	5	24	4	0.48	529	FW
Centrales	52	35	455	72	1	272	1	UND*	592	EURY
Chlamydomonas	39	2	61	27	10	12	6	0.25	635	EURY
Crucigenia	32	0	12	3	14	5	11	0.24	32	FW
Cryptomonas	35	12	405	201	2	10	8	0.14	5199	FW
Dinoflagellates	37	2	69	19	7	9	10	0.22	286	EURY
Euglena	39	0	42	13	12	10	9	0.27	218	EURY
Microcystis	33	8	136	42	4	12	7	0.15	693	FW
Oscillatoria	34	1	59	21	11	16	5	0.18	381	EURY
Pennales	50	5	64	14	8	34	2	0.72	152	EURY
ASSOCIATES										
Lepocinclis	19	0	6	2	21	0	---	0.11	49	FW
Phacotus	14	0	11	4	15	0	---	0.06	68	EURY
Scenedesmus	29	0	7	2	19	2	12	0.23	13	FW

[†] See Materials and Methods section in text.

*Undefined.

agreement as to the "best" and "worst" stations. There was no significant concordance within taxa, which indicates no consistent relationship among taxa dominance (Table 2). Group II comprises 2 taxa. Group I was found together in 7 samples. Group II was found together in 7 samples.

Selected statistics and characterizations of the taxa for fall groups are given in Table A412. Taxa of Group I were frequent members of the fall phytoplankton community, being present in at least 70% of the samples. Centric diatoms dominated in 12 of the 20 samples; Cryptomonas dominated in 8 of the 20; and the remaining taxa were less dominant (<6 out of 20). Mean abundances for Anabaena, Centric diatoms, Ankistrodesmus, Microcystis, Cryptomonas, and Oscillatoria were one order greater than the other taxa. Group I is composed equally of euryhaline and freshwater taxa. The associates of Group I, Merismopedia and Phacotus, are euryhaline.

4. Winter Groups

Figure 2 gives recurrent groups for phytoplankton during winter months (December, January, and February). Three groups were formed. Group I is composed of eight taxa with one associate member. Groups II and III are each made up of two members.

Group I was found together in five samples. Taxa of Group I did not "agree" significantly as to the "best" and "worst" stations. There was significant concordance within taxa, indicating the following dominance relationship: Centrales > Chlamydomonas > Cryptomonas > Pennales > Ankistrodesmus > Euglena > Green coccoid > Anabaena (Table 2).

Group II was found together in three samples: from offshore of Lacombe (S4), at South Point (S105), and the Chef Menteur Pass marsh (S107). Group III was found together in two samples: from offshore of Walker Canal (S10) and at Bayou Lacombe (S204).

Table A412. Selected Statistics for Phytoplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for Fall (October and November of 1978[†]

Taxa Group	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/Mean	Character
GROUP I										
Anabaena	17	3	227	133	4	5	7	0.28	1563	FW
Ankistrodesmus	19	1	164	103	5	6	6	0.52	1282	FW
Centrales	20	12	240	56	3	159	1	UND*	263	EURY
Cryptomonas	19	8	318	104	2	68	2	0.46	675	FW
Dinoflagellates	20	1	45	13	8	17	4	UND*	74	EURY
Microcystis	14	1	171	69	6	4	8	0.19	799	FW
Oscillatoria	15	4	459	218	1	8	5	0.18	2079	EURY
Pennales	17	6	54	16	7	22	3	0.38	89	EURY
ASSOCIATES										
Merismopedia	8	0	18	11	12	0	---	0.10	139	EURY
Phacotus	8	0	5	2	14	0	---	0.14	18	EURY
GROUP II										
Chlamydomonas	9	0	20	13	10	0	---	0.01	165	EURY
Euglena	11	11	12	6	13	2	9	0.19	68	EURY

[†] See Materials and Methods section in text.

*Undefined.

Selected statistics and characterizations for the taxa of winter groups are given in Table A413. Taxa of Group I were frequent members of the phytoplankton community during winter and were present in >54% of the samples (13 out of 24 for Green coccoid). Centric diatoms dominated 71% of the winter samples; *Cryptomonas*, *Chlamydomonas*, and pennate diatoms were present a lesser extent (<37%). Mean abundances were almost one order of magnitude greater for Centric diatoms *Chlamydomonas* and *Cryptomonas* than for the other taxa. Centric diatoms *Chlamydomonas* and *Cryptomonas* were more highly aggregated than the other taxa (see k-values and variance:mean ratios).

Table A413. Selected Statistics for Phytoplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for Winter (December, January, and February) of 1978†

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
<u>GROUP I</u>										
Anabaena	14	0	2	1	12	0.4	8	0.43	4	FW
Ankistrodesmus	22	0	53	10	5	48	5	0.54	45	FW
Centrales	24	17	299	70	1	171	1	UND*	391	EURY
Chlamydomonas	23	8	229	61	2	104	2	0.52	385	EURY
Cryptomonas	22	9	155	45	3	56	3	0.42	313	FW
Euglena	17	1	19	7	8	2	[illegible]	0.29	54	EURY
Green coccoid	13	1	9	4	11	1	[illegible]	0.20	37	EURY
Pennales	23	5	84	18	4	55	4	0.65	89	EURY
<u>ASSOCIATE</u>										
Dinoflagellates	10	1	20	8	7	0	---	0.10	68	EURY
<u>GROUP II</u>										
Microcystis	3	0	1	1	18	0	---	0.03	9	FW
Phacotus	4	0	1	1	15	0	---	0.05	10	EURY
<u>GROUP III</u>										
Characium	2	0	0.02	0.02	31	0	---	0.02	0.40	FW
Trachelomonas	2	0	0.02	0.02	30	0	---	0.02	0.28	FW

†See Materials and Methods section in text.

*Undefined.

APPENDIX 5

MICROZOOPLANKTON

A. Taxa, Distributions, and Abundances by Season

B. Recurrent Groups by Season: Distributions, Statistics, and Characterizations

Table A51. Microzooplankton Taxa Identified from Stations in Lake Pontchartrain, LA, During 1978

	Taxa	Character	Common Name
1.	Synchaeta spp.	B.W.	Rotifer
2.	Copepoda nauplii		Copepod
3.	Brachionus plicatilis	B.W.	Rotifer
4.	Brachionus pterodinoides	F.W.	Rotifer
5.	Mytilina mucronata	F.W.	Rotifer
6.	Trichocerca weberi	T.P.	Rotifer
7.	Notholca acuminata	F/B.W.	Rotifer
8.	Notholca marina	B.W.	Rotifer
9.	Notholca labis	F/B.W.	Rotifer
10.	Notholca bipalium	F/B.W.	Rotifer
11.	Keratella americana	F.W.	Rotifer
12.	Keratella quadrata	F.W.	Rotifer
13.	Keratella cochlearis	F.W.	Rotifer
14.	Kellicottia bostoniensis	F.W.	Rotifer
15.	Platyas quadricornis	F.W.; T.P.	Rotifer
16.	Brachionus patulus	F.W.; T.P.	Rotifer
17.	Lecane spp.	F.W.; T.P.	Rotifer
18.	Brachionus spp.		Rotifer
19.	Trichocerca capucina	F.W.; T.P.	Rotifer
20.	Trichotria spp.		Rotifer
21.	Cladocera	F.W.	Cladocera
22.	Polyarthra spp.	F.W.	Rotifera
23.	Nematoda		Nematode
24.	Gastropus minor	F.W.	Rotifer
25.	Notholca striata	B.W.	Rotifer
26.	Cirripedia nauplii	B.W.	Barnacle
27.	Hexarthra spp.	F.W.	Rotifer
28.	Daphnidae	F.W.	Cladocera
29.	Ceriodaphnia spp.	F.W.	Cladocera
30.	Asplanchna spp.	F/B.W.	Rotifer
31.	Notholca spp.	F/B.W.	Rotifer
32.	Lepadella spp.		Rotifer
33.	Harpacticoida	B	Copepod

Table A51. (Continued)

	Taxa	Character	Common Name
34.	Cyclopoida copepodi		Copepod
35.	Brachionus urceolaris	F.W.	Rotifer
36.	Cyclopoida adult		Copepod
37.	Asplanchna priodonta	F.W.	Rotifer
38.	Trichocerca spp.	F.W.	Rotifer
39.	Keratella valga	F.W.	Rotifer
40.	Cephalodella spp.	F.W.	Rotifer
41.	Texadina sphinctosoma	T.P.B.	Mollusk
42.	Polychaeta	B	Polychaeta
43.	Brachionus havanaensis	F.W.	Rotifer
44.	Bdelloida rotifer	B	Rotifer
45.	Gastropus spp.	F.W.	Rotifer
46.	Tardigrada	F.W.	Tardigrad
47.	Asplanchna brightwelli	F.W.	Rotifer
48.	Chaoborus spp.	F.W.	Insect larvae
49.	Keratella tropica	F.W.	Rotifer
50.	Species 'A'		
51.	Brachionus rubens	F.W.	Rotifer
52.	Brachionus novae-zealandiae	F.W.	Rotifer
53.	Brachionus angularis	F/B.W.	Rotifer
54.	Trichocerca rousseleti	F.W.; T.P.	Rotifer
55.	Polyarthra remata	F.W.	Rotifer
56.	Colurella spp.	F.W.	Rotifer
57.	Brachionus calyciflorus	F/B.W.	Rotifer
58.	Trichocerca elongata	F.W.	Rotifer
59.	Keratella cochlearis f. tecta	F.W.	Rotifer
60.	Decapoda zoeae	B.W.	Decapod
61.	Unknown		
62.	Asplanchna girodi-brightwelli complex	F.W.	Rotifer
63.	Polyarthra vulgaris	F.W.	Rotifer
64.	Polyarthra major-euryptera	F.W.	Rotifer
65.	Brachionidae - male		Rotifer
66.	Isopoda		Isopod

Table A51. (Continued)

	Taxa	Character	Common Name
67.	Conochilus sp. (dossuarius?)	F.W.	Rotifer
68.	Testudinella patina	F.W.	Rotifer
69.	Bosminopsis deitersi	F.W.	Cladocera
70.	Filinia pejleri	F/B.W.	Rotifer
71.	Calanoida copepodid		Copepod
72.	Calanoida adult (Acartia tonsa)		Copepod
74.	Mysid shrimp		Mysid shrimp
75.	Unidentified rotifer: 'SpX'		Rotifer
76.	Unidentified copepoda: 'SpX'	F.W.	Rotifer
77.	Anureopsis fissa	F.W.	Rotifer
78.	Brachionus falcatus	F.W.	Rotifer
79.	Polyarthra euryptera	F.W.	Rotifer
80.	Chironomidae	B.W.	Insect larvae
82.	Macrochaetus spp.	F.W.; T.P.	Rotifer
83.	Euchlanis spp.	F.W.	Rotifer
84.	Brachionus quadridentatus	F.W.	Rotifer
85.	Rotaria spp.	B	Rotifer
86.	Keratella spp.	F.W.	Rotifer
87.	Ostracoda		Ostracod
89.	Moina micrura	F.W.; T.P.	Cladocera
91.	Brachionus caudatus f. vulgaris	F.W.	Rotifer
92.	Insect larvae		Insect larvae
93.	Brachionus caudatus	F.W.	Rotifer
94.	Trichocerca pusilla	F.W.	Rotifer
96.	Keratella cochlearis f. hispida	F.W.	Rotifer

B.W. = Brackish water

F.W. = Fresh water

F/B.W. = Fresh or brackish water

T.P. = Tychoplanktonic

T.P.B. = Tychoplanktonic and benthic

B. = Benthic

A. Taxa, Distributions, and Abundances by Season

1. Spring

Abridged microzooplankton taxa and abundance categories for spring months, grouped into lake, tidal passes, and marsh stations, are given in Table A52; detailed data per taxa per station are given in Table A53.

During the spring of 1978, 47 microzooplankton taxa were identified from 38 samples. Thirty taxa were identified from lake stations; 24 taxa, from the tidal passes; and 39 taxa, from marsh stations. Five taxa were found only at lake stations. They were: *Notholca labis*, *Cephalodella* spp., *Brachionus havanaensis*, *B. rubens*, and decapod zoeae. Two taxa were found only in the tidal passes: *Tardigarda* and *Keratella tropica*. Twelve taxa were found only at marsh stations: *N. bipalium*, *Trichotria* spp., *Daphnidae*, *Asplanchna* spp., *Lepadella* spp., *A. priodonta*, Bdelloida rotifer, *Gastropus* spp., *A. brightwelli*, *Chaoborus* spp., *B. novae-zealandiae*, and Cladocera. There were 23 and 24 taxa, respectively, at the Lacombe marsh and bayou stations (cf. Table A53).

Four taxa were highly abundant; 10 taxa including 9 new taxa were abundant; 14 taxa including 11 new taxa were moderately abundant; 25 taxa including 17 new taxa were common; 14 taxa including 6 new taxa were rare; 19 taxa were unique or restricted in their distribution. There were more abundant and common taxa in the marsh stations than in the lake or pass stations. More unique taxa (those restricted to one habitat) were found in the marshes than in the lake and pass stations.

Table A52. Microzooplankton Abundance Categories Combined for Stations in the Lake, Passes, and Marshes During Spring (March, April, and May) 1978 in Lake Pontchartrain, LA, Environs

Abundance	Lake			Passes		
$n > 10^4$ Highly Abundant	Synchaeta spp. (1) Copepoda nauplii (2)	B. plicatilis (3) B. angularis (53)	(4)	Synchaeta spp. (1) Copepoda nauplii (2)		(2)
$10^4 \geq n > 10^3$ Abundant	M. mucronata (5) F. pejleri (70) Calanoida copepodid (71) Calanoida adult (A. tonsa) (72)		(4)	B. angularis (53) F. pejleri (70) Calanoida copepodid (71)		(3)
$10^3 \geq n > 10^2$ Moderately Abundant	K. americana (11) Cirripedia nauplii (26) Harpacticoida (33)	Cyclopoida copepodid (3[illegible]) Colurella spp. (56)	(5)	B. plicatilis (3) Cirripedia nauplii (26) Harpacticoida (33)	Cyclopoida copepodid (34) Polychaeta (42) Calanoida adult (A. tonsa) (7[illegible])	(6)
$10^2 \geq n > 10^1$ Common	N. acuminata (7) N. marina (8) K. quadrata (12) Polyarthra spp. (22) B. urceolaris (35) K. valga (39) T. sphinctosoma (41) B. havanaensis (43)		(8)	M. mucronata (5) N. marina (8) K. americana (11) K. cochlearis (13) K. bostoniensis (14) B. urceolaris (35) T. sphinctosoma (41) Tardigrada (46)	Species "A" (50) Colurella spp. (56)	(10)
$10^1 \geq n > 10^0$ Rare	N. labia (9) K. cochlearis (13) Lecane spp. (17) T. capucina (19)	Cyclopoida adult (36) Cephalodella spp. (40) B. rubens (51) Decapoda zoeae (60)	(9)	K. quadrata (12) K. valga (39) K. tropica (49)		(3)
Unique Taxa	N. labia (9) Cephalodella spp. (40) B. havanaensis (43) B. rubens (51) Decapoda zoeae (60)		(5)	Tardigrada (46) K. tropica (49)		(2)
Total Taxa			30			24

Table A52. (Continued)

	Marshes		New Taxa*
$n > 10^4$ Highly Abundant	Synchaeta spp. (1) Copepoda nauplii (2)		4
	(2)		
$10^4 \geq n > 10^3$ Abundant	N. marina (8) K. americana (11) K. cochlearis (13) Polyarthra spp. (22)	Cyclopoida copepodid (34) B. angularis (53) Calanoida copepodid (71)	9
	(7)		
$10^3 \geq n > 10^2$ Moderately Abundant	B. plicatilis (3) K. bostoniensis (14) T. capucina (19) Cladocera (21) Cirripedia nauplii (26) Asplanchna spp. (30)	Harpacticoida (33) Cyclopoida adult (36) A. priodonta (37) Gastropus spp. (45) Calanoida adult (A. tonsa) (72)	11
	(11)		
$10^2 \geq n > 10^1$ Common	M. mucronata (5) N. acuminata (7) N. bipalium (10) K. quadrata (12) B. patulus (16) Lecane spp. (17) Trichotria spp. (20 Daphnidae (28)	Lepadella spp. (32) B. urceolaris (35) T. sphinctosoma (41) Bdelloida rotifer (44) A. brightwelli (47) Chaoborus spp. (48) Species "A" (50) F. pejleri	17
	(16)		
$10^1 \geq n > 10^0$ Rare	K. valga (39) Polychaeta (42) B. novae-zealandiae (52)		6
	(3)		
Unique Taxa	N. bipalium (10) Trichotria spp. (20) Cladocera (21) Daphnidae (28) Asplanchna spp. (30) Lepadella spp. (32)	A. priodonta (37) Bdelloida rotifer (44) Gastropus spp. (45) A. brightwelli (47) Chaoborus spp. (48) B. novae-zealandiae (52)	19
	(12)		
Total Taxa	39		(47)

*New taxa not present in previous abundance categories.

Table A53. Abundances of Microzooplankton Taxa m^{3} During Spring (March, April, and May) of 1978 in Lake Pontchartrain, LA, by Individual Stations

Species	Species Number	Lake Proper						
		West		Mid		East		
		1	10	12	4	5	105	$\bar{X}$
Synchaeta spp.	1	29529	113821	23391	1655	6066	14128	31432
Copepoda nauplii	2	20159	60112	94287	107967	38462	140273	76877
Brachionus plicatilis	3	42	404	11827		464	55159	11316
Mytilina mucronata	5		5009	23		2917	979	1488
Notholca acuminata	7				160			27
Notholca marina	8	13		96	384	60	25	96
Notholca labia	9	20			26			8
Notholca bipalium	10							
Keratella americana	11	18	32	1165				202
Keratella quadrata	12	64	242				20	54
Keratella cochlearia	13				25			4
Kellicottia bostoniensis	14							
Brachionus patulus	16			23				4
Lecane spp.	17	8		23				5
Trichocerca capucina	19	6						1
Trichotria spp.	20							
Cladocera	21							
Polyarthra spp.	22		16		52	27		16
Cirripedia nauplii	26	35		46	472	293	201	175
Daphnidae	28							
Asplanchna spp.	30							
Lepadella spp.	32							
Harpacticoida	33		40		1010	120		195
Cyclopoida copepodid	34	257	107	181	236	170	111	177
Brachionus urceolaris	35				370			62
Cyclopoida adult	36	9						2
Asplanchna priodonta	37							
Keratella valga	39	12		233				41
Cephalodella spp.	40				26			4
Texadina sphinctosoma	41	35			444	25	57	94
Polychaeta	42							
Brachionus havanaensis	43	6		70				13
Bdelloida rotifer	44							
Gastropus spp.	45							
Tardigrada	46							
Asplanchna brightwelli	47							
Chaoborus spp.	48							
Keratella tropica	49							
Species "A"	50							
Brachionus rubens	51		48					8
Brachionus novae-zealandiae	52							
Brachionus angularis	53	2628	15971	170633	4913	7014	274002	79194
Colurella spp.	56					13	2797	468
Decapoda zoeae	60					13		2
Filinia pejleri	70	16		2912		290	13333	2759
Calanoida copepodid	71	3452	16264	6685	9080	5832	18476	9965
Calanoida adult (*Acartia tonsa*)	72	51	5452	597	961	2971	1544	1929
	$\bar{X}$	619	2390	3431	1404	711	5726	

Table A53. (Continued)

Species	Species Number	Passes 6	7	8	X̄	Marshes 110	107	104	[illegible]	X̄
Synchaeta spp.	1	5070	25620	230354	66015	91700	19042	1688	12157	31147
Copepoda nauplii	2	43022	53662	53556	50080	41571	65671	38151	70697	54023
Brachionus plicatilis	3	81	411	48	180	1193	56	182		358
Mytilina mucronata	5	160	51		70		265			66
Notholca acuminata	7					104			104	52
Notholca marina	8	191			64	4696	265	414		1344
Notholca labis	9									
Notholca bipalium	10					23		25		12
Keratella americana	11			32	11			1210	5238	1612
Keratella quadrata	12			16	5				307	77
Keratella cochlearis	13	32			11		120	545	3722	1097
Kellicottia bostoniensis	14	32			11			263	141	101
Brachionus patulus	16							36	68	26
Lecane spp.	17								147	37
Trichocerca capucina	19							73	338	103
Trichotria spp.	20								338	85
Cladocera	21					118			424	136
Polyarthra spp.	22								5638	1410
Cirripedia nauplii	26	395	759	26	393	191	398			147
Daphnidae	28							347		87
Asplanchna spp.	30								1218	304
Lepadella spp.	32							73		18
Harpacticoida	33	199	131		110	811	178	87	73	237
Cyclopoida copepodid	34	367	566	783	572	404	221	2415	12388	3857
Brachionus urceolaris	35			48	16			291	37	82
Cyclopoida adult	36						56	196	1448	425
Asplanchna priodonta	37								513	128
Keratella valga	39	3			1	11				3
Cephalodella spp.	40									
Texadina sphinctosoma	41		34		11		149			37
Polychaeta	42	223	445		223			36		9
Brachionus havanaensis	43									
Bdelloida rotifer	44								135	34
Gastropus spp.	45							36	1489	381
Tardigrada	46	32			11					
Asplanchna brightwelli	47							327		82
Chaoborus spp.	48							73		18
Keratella tropica	49			16	5					
Species "A"	50	114	51	16	61		116			29
Brachionus rubens	51									
Brachionus novae-zealandiae	52						19			5
Brachionus angularis	53	2386	1607	5528	3174	2790	1885	763	2030	1867
Colurella spp.	56	148			50					
Decapoda zoeae	60									
Filinia pejleri	70	2505	111	4768	2461	95	260			89
Calanoida copepodid	71	6342	6396	7849	6863	4553	7967	2214	73	3702
Calanoida adult (Acartia tonsa)	72	2429	171	16	855	312	336	226	[illegible]82	289
	X̄	700	1022	3330		1633	1066	546	1308	

2. Summer

Abridged microzooplankton taxa and abundance categories for summer months, grouped into lake, tidal passes, and marsh stations, are given in Table A54; detailed data per taxa per station are given in Table A55.

During the summer of 1978, 68 microzooplankton taxa were identified from 52 samples. Thirty-nine taxa were identified from lake stations; 36 taxa, from the tidal passes; and 57 taxa, from the marsh stations. Three taxa were found only at the lake stations: *Asplanchna brightwelli*, *Brachionus rubens*, and *B. calyciflorus*. Six taxa were unique to the tidal passes during the summer months: Mysid shrimp, unidentified rotifer, unidentified copepod, *Anureopsis fissa*, insect larvae, and *Keratella cochlearis* f. *hispida*. Twenty taxa were unique to the marshes: *Trichocerca weberi*, *Keratella quadrata*, *Kellicottia bostoniensis*, Nematoda, *Keratella valga*, Bdelloida rotifer, *Brachionus novae-zealandiae*, *Keratella cochlearis* f. *tecta*, unknown, *Polyarthra vulgaris*, *Testudinella patina*, *Polyarthra euryptera*, *Macrochaetus* spp., *Brachionus quadridentatus*, *Keratella* sp., Ostracoda, *Moina micrura*, *Brachionus caudatus* f. *vulgaris*, *Brachionus caudatus*, and *Trichocerca pusilla*.

Seventeen taxa were highly abundant. Twenty-three taxa including 15 new taxa and 18 taxa including 12 new taxa, respectively, were abundant to moderately abundant. Twenty-six taxa including 15 new taxa were common. There were 23 taxa that were rare.

3. Fall

Abridged microzooplankton taxa and abundance categories for fall months, grouped into lake, tidal passes, and marsh stations, are given in Table A56; detailed data per taxa per station are given in Table A57.

Table A54. Microzooplankton Abundance Categories Combined for Stations in the Lake, Passes, and Marshes During Summer (June, July, August, and September) 1978 in Lake Pontchartrain, LA, Environs

Abundance	Lake		Passes	
$n > 10^4$ Highly Abundant	Copepoda nauplii (2) B. plicatilis (3) Cyclopoida copepodid (34) T. sphinctosoma (41) B. angularis (53)	Conochilus sp. (67) B. deitersi (69) F. pejleri (70) Calanoida copepodid (71) Calanoida adult (A. tonsa) (72)	Synchaeta spp. (1) Copepoda nauplii (2) B. plicatilis (3) B. angularis (53) B. deitersi (69)	F. pejleri (70) Calanoida copepodid (71) Calanoida adult (A. tonsa) (72)
	(10)		(8)	
$10^4 \geq 10^3$ Abundant	Synchaeta spp. (1)		K. cochlearis (13) Cyclopoida copepodid (34) Trichocerca spp. (38) T. sphinctosoma (41) Polychaeta (42) B. havanaensis (43)	
	(1)		(6)	
$10^3 \geq n > 10^2$ Moderately Abundant	M. mucronata (5) K. americana (11) Polyarthra spp. (22) Cirripedia nauplii (26) Harpacticoida (33)	Cyclopoida adult (36) Trichocerca spp. (38) A. brightwelli (47) B. falcatus (78)	Cirripedia nauplii (26) Harpacticoida (33) P. remata (55) Mysid shrimp (74)	
	(9)		(4)	
$10^2 \geq n > 10^1$ Common	K. cochlearis (13) B. patulus (16) Lecane spp. (17) G. minor (24) Daphnidae (28) A. priodonta (37) Polychaeta (42)	Decapoda zoeae (60) A. girodi-brightwelli complex (62)	M. mucronata (5) Brachionus spp. (18) Cyclopoida adult (36) A. girodi-brightwelli complex (62) Isopoda (66) Conochilus sp. (67)	Unidentified copepoda "Sp X" (76)
	(9)		(7)	
$10^1 \geq n > 10^0$ Rare	Asplanchna spp. (30) B. urceolaris (35) B. havanaensis (43) Tardigrada (46) B. rubens (51)	P. remata (55) B. calyciflorus (57) Chironomidae (80) Euchlanis spp. (83) Rotaria spp. (85)	B. patulus (16) Lecane spp. (17) Cladocera (21) Daphnidae (28) A. priodonta (37) Tardigrada (46)	Decapoda zoeae (60) Unidentified rotifer "Sp X" (75) A. fissa (77) Insect larvae (92) K. cochlearis f. hispida (96)
	(10)		(11)	
Unique Taxa	A. brightwelli (47) B. rubens (51) B. calyciflorous (57)		Mysid shrimp (74) Unidentified rotifer "Sp X" (75) Unidentified copepoda "Sp X" (76) A. fissa (77) Insect larvae (92) K. cochlearis f. hispida (96)	
	(3)		(6)	
Total Taxa	39		36	

Table A54. (Continued)

	Marshes		New Taxa*
$n > 10^4$ Highly Abundant	Copepoda nauplii (2) K. americana (11) Polyarthra spp. (22) Daphnidae (28) Asplanchna spp. (30) Cyclopoida copepodid (34)	Cyclopoida adult (36) Trichocerca spp.(38) Conochilus sp. (67) B. deitersi (69) Calanoida copepodid (71)	17
	(11)		
$10^4 \geq 10^3$ Abundant	Synchaeta spp. (1) B. plicatilis (3) K. cochlearis (13) B. patulus (16) Lecane spp. (17) Cladocera (21) C. minor (24) Harpacticoida (33) A. priodonta (37) T. sphinctosoma (41)	B. havanaensis (43) B. angularis (53) P. remata (55) K. cochlearis f. tecta (59) Decapoda zoeae (60) A. girodi-brightwelli complex (62) F. pejleri (70) Calanoida adult (A. tonsa) (72) P. euryptera (79) Chironomidae (80)	15
	(20)		
$10^3 \geq n > 10^2$ Moderately Abundant	Cirripedia nauplii (26) Bdelloida rotifer (44) Unknown (61) P. vulgaris (63) Macrochaetus spp. (82)	Euchlanis spp. (83) M. micrura (89) B. caudatus (93)	12
	(8)		
$10^2 \geq n > 10^1$ Common	T. weberi (6) K. quadrata (12) K. bostoniensis (14) Brachionus spp. (18) Nematoda (23) B. urceolaris (35) K. valga (39)	Tardigrada (46) B. novae-zealandiae (52) T. patina (68) B. falcatus (78) Keratella spp. (86)	15
	(14)		
$10^1 \geq n > 10^0$ Rare	Isopoda (66) B. quadridentatus (84) Rotaria spp. (85) T. pusilla (94)		9
	(4)		
Unique Taxa	T. weberi (6) K. quadrata (12) K. bostoniensis (14) Nematoda (23) K. valga (39) Bdelloida rotifer (44) B. novae-zealandiae (52) K. cochlearis f. tecta (59) Unknown (61) P. vulgaris (63)	T. patina (68) P. euryptera (79) Macrochaetus spp. (82) B. quadridentatus (84) Keratella spp. (86) Ostracoda (87) M. micrura (89) B. caudatus f. vulgaris (91) B. caudatus (93) T. pusilla (94)	29
	(20)		
Total Taxa	57		(68)

*New taxa not present in previous abundance categories.

Table A55. Abundances of Microzooplankton Taxa m^3 During Summer (June, July, August, and September) of 1978 in Lake Pontchartrain, LA, by Individual Stations

Species	Species Number	Lake Proper: West 1	West 10	Mid 12	Mid 4	East 5	East 105	$\bar{X}$
Synchaeta spp.	1	3494	59	290	92	2195	3017	1524
Copepoda nauplii	2	288322	42627	84012	164282	271101	311394	193623
Brachionus plicatilis	3	30353	116043	24612	39709	23161	94369	54708
Mytilina mucronata	5				1475			246
Trichocerca weberi	6							
Keratella americana	11	2725	764		902	1174	43	934
Keratella quadrata	12							
Keratella cochlearis	13				85		11	16
Kellicottia bostoniensis	14							
Brachionus patulus	16	122			67			32
Lecane spp.	17	4	17	68	134			37
Brachionus spp.	18							
Cladocera	21							
Polyarthra spp.	22					1167		194
Nematoda	23							
Gastropus minor	24		[illegible]					[illegible]
Cirripedia nauplii	26	2101	[illegible]	465	92	1910	919	[illegible]
Daphnidae	28				67			11
Asplanchna spp.	30		2				21	4
Harpacticoida	33	4296	96	164			204	793
Cyclopoida copepodid	34	77811	705	10	2516	1434	4155	14438
Brachionus urceolaris	35		5					1
Cyclopoida adult	36	2381	24	19		23	843	548
Asplanchna priodonta	37	4	96					17
Trichocerca spp.	38	2337	137	246	495	1167	11	732
Keratella valga	39							
Texadina sphinctosoma	41	2222	1675	1072	16398	23491	22413	11212
Polychaeta	42		141				11	25
Brachionus havanaensis	43	8						1
Bdelloida rotifer	44							
Tardigrada	46		5					1
Asplanchna brightwelli	47		2197					366
Brachionus rubens	51	13						2
Brachionus novae-zealandiae	52							
Brachionus angularis	53	348712	32068	122126	48846	99254	96843	124642

Table A55. (Continued)

Species	Species Number	Passes 6	Passes 7	Passes 8	$\bar{X}$	Marshes 110	Marshes 107	Marshes 104	Marshes 204	$\bar{X}$
Synchaeta spp.	1	33176	2784	17	11992	1155	8915	3949	9893	5978
Copepoda nauplii	2	682700	93929	37622	271417	8729	129614	56241	389833	146104
Brachionus plicatilis	3	63576	7227	60112	43639	1616	9048	16342	107	6778
Mytilina mucronata	5			44	15					
Trichocerca weberi	6							92		23
Keratella americana	11					76		44862	82905	31986
Keratella quadrata	12							183	40	56
Keratella cochlearis	13	27972	1119		9697		645	11964	7836	5111
Kellicottia bostoniensis	14							92	119	53
Brachionus patulus	16			24	8	19		1621	8431	2518
Lecane spp.	17		27		9	67	1533	807	5701	2027
Brachionus spp.	18	188			63		95	183		70
Cladocera	21	24			8				8392	2098
Polyarthra spp.	22							2655	37372	10007
Nematoda	23						95			24
Gastropus minor	24							544	17796	4585
Cirripedia nauplii	26	990	37	345	457	29	652	122		201
Daphnidae	28			24	8		95	3815	190703	48653
Asplanchna spp.	30							366	246155	61630
Harpacticoida	33	1061	808	1	623		5074	216	40	1332
Cyclopoida copepodid	34	24379	1674	2688	9580	177	907	5140	33818	10010
Brachionus urceolaris	35					178		19		49
Cyclopoida adult	36	11	30	96	46	5	191	1149	111889	28308
Asplanchna priodonta	37		25		8				10678	2669
Trichocerca spp.	38	4300	365	141	1602	924	1481	7615	66473	19123
Keratella valga	39							207		52
Taxadina sphinctosoma	41	16093	1944	197	6078	91	7246	310		1912
Polychaeta	42	2150	58	24	744					
Brachionus havanaensis	43	188	27		72	5549		549	802	1725
Bdelloida rotifer	44					19		366	53	110
Tardigrada	46			24	8	48				12
Asplanchna brightwelli	47									
Brachionus rubens	51									
Brachionus novae-zealandiae	52					77				19
Brachionus angularis	53	44455	5551	76079	42088	4659	27522	2041		8556

Table A55. (Continued)

Species	Species Number	Passes 6	7	8	$\bar{X}$	Marshes 110	107	104	204	$\bar{X}$
Polyarthra remata	55	2173			724			5180	17380	5640
Brachionus calyciflorus	57									
Keratella cochlearis f. tecta	59							7232	5512	3186
Decapoda zoeae	60	11			4		7	7336	53	1849
Unknown	61							1739		435
Asplanchna girodi-brightwelli	62			217	72	134		7397	12457	4997
Polyarthra vulgaris	63							90	3559	912
Isopoda	66		53		18	19				5
Conochilus sp. (dossuarius?)	67	4	25	154	61	195	32	2620	580045	145723
Testudinella patina	68							310		78
Bosminopsis deitersi	69	4927		30831	11919	29	2554	15955	913428	232991
Filinia pejleri	70	108584	5424	2127	38712	883	8779	4833		3624
Calanoida copepodid	71	177833	26304	7551	70563	2741	47124	2474		13085
Calanoida adult	72	59118	15238	3408	25921	790	21625	1410		5956
Mysid shrimp	74	377			126					
Unidentified rotifer	75		27		9					
Unidentified copepoda	76		53		18					
Anureopsis fissa	77		27		9					
Brachionus falcatus	78							103		26
Polyarthra euryptera	79							285	19308	4898
Chironomidae	80								8392	2098
Macrochaetus spp.	82						286	150		109
Euchlanis spp.	83							452		113
Brachionus quadridentatus	84							19		5
Rotaria spp.	85							19		5
Keratella spp.	86						95			24
Ostracoda	87						95			24
Moina micrura	89							1168		292
Brachionus caudatus f. vulgaris	91							135		34
Insect larvae	92			24	8					
Brachionus caudatus	93					139		310		112
Trichocerca pusilla	94					5				1
Keratella cochlearis f. hispida	96		30		10					
	$\bar{X}$	13783	1789	2437		312	3008	2426	30650	

Table A55. (Continued)

Species	Species Number	Lake Proper: West 1	West 10	Mid 12	Mid 4	East 5	East 105	$\bar{X}$
Polyarthra remata	55	4						1
Brachionus calyciflorus	57	25						4
Keratella cochlearis f. tecta	59							
Decapoda zoeae	60					147		24
Unknown	61							
Asplanchna girodi-brightwelli	62		157					26
Polyarthra vulgaris	63							
Isopoda	66							
Conochilus sp. (dossuarius?)	67	1183342	32	374	84	397	77	197384
Testudinella patina	68							
Bosminopsis deitersi	69			10	67	441	64255	10795
Filinia pejleri	70	11989	48649	22592	47469	111258	31078	45506
Calanoida copepodid	71	23063	8361	24312	39133	92696	41969	38256
Calanoida adult	72	9932	2966	12132	26233	58281	29220	23127
Mysid shrimp	74							
Unidentified rotifer	75							
Unidentified copepoda	76							
Anureopsis fissa	77							
Brachionus falcatus	78	773	157					155
Polyarthra euryptera	79							
Chironomidae	80	30						5
Macrochaetus spp.	82							
Euchlanis spp.	83		5					1
Brachionus quadridentatus	84							
Rotaria spp.	85	30						5
Keratella spp.	86							
Ostracoda	87							
Moina micrura	89							
Brachionus caudatus f. vulgaris	91							
Insect larvae	92							
Brachionus caudatus	93							
Trichocerca pusilla	94							
Keratella cochlearis f. hispida	96							
	$\bar{X}$	21913	2830	3214	4265	7575	7702	

Table A56. Microzooplankton Abundance Categories Combined for Stations in the Lake, Passes, and Marshes During Fall (October and November) 1978 in Lake Pontchartrain, LA, Environs

Abundance	Lake	Passes
$n > 10^4$ Highly Abundant	Copepoda nauplii (2) Calanoida adult (A. tonsa) (72)	Copepoda nauplii (2) Calanoida adult (A. tonsa) (72)
	(2)	(2)
$10^4 \geq n > 10^3$ Abundant	Synchaeta spp. (1) B. angularis (53) Calanoida copepodid (71)	Cyclopoida copepodid (34) Calanoida copepodid (71)
	(3)	(2)
$10^3 \geq n > 10^2$ Moderately Abundant	B. plicatilis (3) Cyclopoida copepodid (34)	Synchaeta spp. (1) Harpacticoida (33) Cyclopoida adult (36) T. sphinctosoma (41) B. angularis (53)
	(2)	(5)
$10^2 \geq n > 10^1$ Common	Cirripedia nauplii (26) Cyclopoida adult (36) T. sphinctosoma (41) Polychaeta (42) T. patina (68)	B. plicatilis (3) Cirripedia nauplii (26) Conochilus sp. (67)
	(5)	(3)
$10^1 \geq n > 10^0$ Rare	B. patulus (16) Lecane spp. (17) Harpacticoida (33) Conochilus sp. (67) K. cochlearis f. hispida (96)	K. cochlearis (13) B. calyciflorus (57) T. patina (68) F. pejleri (70)
	(5)	(4)
Unique Taxa	K. cochlearis f. hispida (96)	B. calyciflorus (57)
	(1)	(1)
Total Taxa	17	16

Table A56. (Continued)

	Marshes		New Taxa*
$n > 10^4$ Highly Abundant	Copepoda nauplii (2)		2
	(1)		
$10^4 \geq n > 10^3$ Abundant	B. angularis (53) Calanoida copepodid (71) Calanoida adult (A tonsa) (72)		4
	(3)		
$10^3 \geq n > 10^2$ Moderately Abundant	Synchaeta spp. (1) B. plicatilis (3) Cirripedia nauplii (26) Cyclopoida copepodid (34) T. sphinctosoma (41)		5
	(5)		
$10^2 \geq n > 10^1$ Common	N. marina (8) K. americana (11) K. cochlearis (13) K. bostoniensis (14) Lecane spp. (17) T. capucina (19) Harpacticoida (33) B. urceolaris (35) Cyclopoida adult (36)	K. valga (39) Polychaeta (42) B. havanaensis (43) T. patina (68) F. pejleri (70) Euchlanis spp. (83) Rotaria spp. (85) B. caudatus (93)	16
	(17)		
$10^1 \geq n > 10^0$ Rare	M. mucronata (5) N. acuminata (7) N. labis (9) B. patulus (16) Trichotria spp. (20) C. minor (24)	Lepadella spp. (32) Trichocerca spp. (38) Conochilus sp. (67) B. deitersi (69) Chironomidae (80) B. quadridentatus (84)	13
	(12)		
Unique Taxa	M. mucronata (5) N. acuminata (7) N. marina (8) N. labis (9) K. americana (11) K. bostoniensis (14) T. capucina (19) Trichotria spp. (20) C. minor (24) Lepadella spp. (32)	B. urceolaris (35) Trichocerca spp. (38) K. valga (39) B. havanaensis (43) B. deitersi (69) Chironomidae (80) Euchlanis spp. (83) B. quadridentatus (84) Rotaria spp. (85) B. caudatus (93)	22
	(20)		
Total Taxa	38		(40)

* New taxa not present in previous abundance categories.

Table A57. Abundances of Microzooplankton Taxa m^3 During Fall (October and November) of 1978 in Lake Pontchartrain, LA, by Individual Stations

		Lake Proper						
		West		Mid		East		
Species	Species Number	1	10	12	4	5	105	$\bar{x}$
Synchaeta spp.	1	274	42		1016	3205	2451	1165
Copepoda nauplii	2	4104	13769	16236	76487	6064	19453	22685
Brachionus plicatilis	3	124	357	1767			85	389
Mytilina mucronata	5							
Notholca acuminata	7							
Notholca marina	8							
Notholca labis	9							
Keratella americana	11							
Keratella cochlearis	13							
Kellicottia bostoniensis	14							
Brachionus patulus	16				53			9
Lecane spp.	17						4	1
Trichocerca capucina	19							
Trichotria spp.	20							
Gastropus minor	24							
Cirripedia nauplii	26	75			107	236	73	82
Lepadella spp.	32							
Harpacticoida	33			38			4	7
Cyclopoida copepodid	34			13	160	623	28	137
Brachionus urceolaris	35							
Cyclopoida adult	36			45		166	21	38
Trichocerca spp.	38							
Keratella valga	39							
Texadina sphinctosoma	41			32			102	22
Polychaeta	42	99						17
Brachionus havanaensis	43							
Brachionus angularis	53	1293		466	10958	20	480	2203
Brachionus calyciflorus	57							
Conochilus sp. (*dossuarius*?)	67	17						3
Testudinella patina	68				107			18
Bosminopsis deitersi	69							
Filinia pejleri	70							
Calanoida copepodid	71	2164	3307	3288	25759	5005	1190	6784
Calanoida adult (*Acartia tonsa*)	72	2711	248[illegible]	1655	54582	8529	1978343	341363
Chironomidae	80							
Euchlanis spp.	83							
Brachionus quadridentatus	84							
Rotaria spp.	85							
Brachionus caudatus	93							
Keratella cochlearis f. *hispida*	96			6				1
	$\bar{x}$	119	219	259	1860	262	22002	

Table A57. (Continued)

Species	Species Number	Passes 6	Passes 7	Passes 8	$\bar{X}$	Marshes 110	Marshes 107	Marshes 104	Marshes 204	$\bar{X}$
Synchaeta spp.	1	1477	1169	17	888	494	106	917	431	487
Copepoda nauplii	2	41585	109147	50198	66977	17356	21245	24493	2880	16493
Brachionus plicatilis	3			89	30	465			6	118
Mytilina mucronata	5								13	3
Notholca acuminata	7								19	5
Notholca marina	8						38	8	13	15
Notholca labis	9								6	2
Keratella americana	11								207	[illegible]
Keratella cochlearis	13			6	2				107	[illegible]
Kellicottia bostoniensis	14								57	22
Brachionus patulus	16								39	[illegible]
Lecane spp.	17					29			23	13
Trichocerca capucina	19						56			14
Trichotria spp.	20								6	2
Gastropus minor	24								6	2
Cirripedia nauplii	26		76	102	59	494	838			333
Lepadella spp.	32								26	6
Harpacticoida	33	314	152	44	170		206	62		67
Cyclopoida copepodid	34	1885	1145	28	1019		719	185	58	241
Brachionus urceolaris	35							47		12
Cyclopoida adult	36	22	795	48	289		189			48
Trichocerca spp.	38								6	2
Keratella valga	39							295	91	96
Texadina sphinctosoma	41		304	17	107	291	568			215
Polychaeta	42					204				51
Brachionus havanaensis	43							62	195	64
Brachionus angularis	53			683	228	552	894	3092	384	[illegible]
Brachionus calyciflorus	57			6	2					
Conochilus sp. (*dossuarius*?)	67		114	129	81			8	2	2
Testudinella patina	68	11			4				45	11
Bosminopsis deitersi	69							16	12	7
Filinia pejleri	70			3	1		5	39		11
Calanoida copepodid	71	398	10348	7343	6030	1802	5455	504	530	2073
Calanoida adult (*Acartia tonsa*)	72	1048431	5995	6634	353687	1047	1931	1028	2263	1567
Chironomidae	80								5	1
Euchlanis spp.	83								44	11
Brachionus quadridentatus	84								13	3
Rotaria spp.	85								66	16
Brachionus caudatus	93							44	11	14
Keratella cochlearis f. *hispida*	96									
	$\bar{X}$	12023	1420	718		250	354	338	84	

During fall of 1978, 40 microzooplankton taxa were identified from 22 samples. Seventeen taxa were found at lake stations; 16 taxa, at the tidal passes; and 38 taxa, at the marshes. One taxon, *Keratella cochlearis* f. *hispida*, was unique to the lake stations. One taxon, *Brachionus calyciflorus*, was unique to the tidal passes. Twenty taxa were unique to the marshes: *Mytilina mucronata*, *Notholca acuminata*, *Notholca marina*, *Notholca labis*, *Keratella americana*, *Kellicottia bostoniensis*, *Trichocerca capucina*, *Trichotria* spp., *Gastropus minor*, *Lepadella* spp., *Brachionus urceolaris*, *Trichocerca* spp., *Keratella valga*, *Brachionus havanaensis*, *Bosminopsis deitersi*, Chironomidae, *Euchlanis* spp., *Brachionus quadridentatus*, *Rotaria* sp., and *Brachionus caudatus*.

Two taxa were highly abundant: Copepoda nauplii and Calanoida adults. Six taxa including 4 new taxa were abundant. Eight taxa including 5 new taxa were moderately abundant. The remaining taxa were, respectively, either common (20 taxa including 16 new taxa) or rare (19 taxa including 13 new taxa).

4. Winter

Abridged microzooplankton taxa and abundance categories for winter months, grouped into lake, tidal passes, and marsh stations, are given in Table A58; detailed data per taxa per station are given in Table A59.

During winter of 1978, 29 microzooplankton taxa were identified from 27 samples. Fifteen taxa were found at lake stations; 16 taxa, at the tidal passes; and 24 taxa, at the marsh stations. Five taxa were unique to the tidal passes: *Keratella quadrata*, *Notholca striata*, *Asplanchna* spp., *Notholca* spp., and *Trichocerca capucina*. Eight taxa

Table A58. Microzooplankton Abundance Categories Combined for Stations in the Lake, Passes, and Marshes During Winter (December, January, and February) 1978 in Lake Pontchartrain, LA, Environs

Abundance	Lake	Passes
$n > 10^4$ Highly Abundant	Synchaeta spp. (1) Copepoda nauplii (2) Calanoida copepodid (71) Calanoida adult (A. tonsa) (72)	Synchaeta spp. (1) Copepoda nauplii (2)
	(4)	(2)
$10^4 \geq n > 10^3$ Abundant		N. labia (9) Calanoida copepodid (71) Calanoida adult (A. tonsa) (72)
		(3)
$10^3 \geq n > 10^2$ Moderately Abundant	N. marina (8)	N. marina (8) K. quadrata (12) K. bostoniensis (14) N. striata (25) Cirripedia nauplii (26) Asplanchna spp. (30)
	(1)	(6)
$10^2 \geq n > 10^1$ Common	N. labia (9) Cirripedia nauplii (26) Harpacticoida (33) Cyclopoida copepodid (34)	N. acuminata (7) T. capucina (19) Notholca spp. (31) Cyclopoida copepodid (34) Cyclopoida adult (36)
	(4)	(5)
$10^1 \geq n > 10^0$ Rare	N. acuminata (7) N. bipalium (10) Lecane spp. (17) Cyclopoida adult (36) B. angularis (53) Conochilus sp. (67)	
	(6)	(0)
Unique Taxa		K. quadrata (12) T. capucina (19) N. striata (25) Asplanchna spp (30) Notholca spp. (31)
	(0)	(5)
Total Taxa	15	16

Table A58. (Continued)

	Marshes		New Taxa*
$n > 10^4$ Highly Abundant	Synchaeta spp. (1) Copepoda nauplii (2) Calanoida copepodid (71) Calanoida adult (A. tonsa) (72)		4
	(4)		
$10^4 \geq n > 10^3$ Abundant	N. marina (8)		2
	(1)		
$10^3 \geq n > 10^2$ Moderately Abundant	N. labia (9) K. americana (11) Cyclopoida copepodid (34) Cyclopoida adult (36) K. valga (39)		9
	(5)		
$10^2 \geq n > 10^1$ Common	N. acuminata (7) N. bipalium (10) Harpacticoida (33 T. patina (68)	Chironomidae (80)	7
	(5)		
$10^1 \geq n > 10^0$ Rare	K. bostoniensis (14) Lecane spp. (13) Brachionus spp. (18) Cladocera (21) Cirripedia nauplii (26) Ceriodaphnia spp. (29)	Trichocerca spp. (38) B. angularis (53) Conochilus sp. (67)	7
	(9)		
Unique Taxa	K. americana (11) Brachionus spp. (18) Cladocera (21) Ceriodaphnia spp. (29) Trichocerca spp. (38)	K. valga (39) T. patina (68) Chironomidae (80)	13
	(8)		
Total Taxa	24		(29)

*New taxa not present in previous abundance categories.

Table A59. Abundances of Microzooplankton m^{3} During Winter (December, January, and February) of 1978 in Lake Pontchartrain, LA, by Individual Stations

Species	Species Number	Lake Proper West 1	Lake Proper West 10	Lake Proper Mid 12	Lake Proper Mid 4	Lake Proper Mid 5	Lake Proper East 103	X̄
Synchaeta spp.	1	27131	5218	263	5279	29769	103579	28540
Copepoda nauplii	2	2337	3860	57404	16856	13093	26249	19966
Notholca acuminata	7	12	16				17	8
Notholca marina	8		1920		106	55	34	352
Notholca labis	9		65				34	16
Notholca bipalium	10		32				8	7
Keratella americana	11							
Keratella quadrata	12							
Keratella cochlearis	13							
Kellicotia bostoniensis	14							
Lecane spp.	17		16					3
Brachionus spp.	18							
Trichocerca capucina	19							
Cladocera	21							
Notholca striata	25							
Cirripedia nauplii	26				85	208	85	63
Ceriodaphnia spp.	29							
Asplanchna spp.	30							
Notholca spp.	31							
Harpacticoida	33		16		106			20
Cyclopoida copepodid	34	72	377				68	86
Cyclopoida adult	36		19					3
Trichocerca spp.	38							
Keratella valga	39							
Brachionus havanaensis	43							
Brachionus angularis	53		16					3
Conochilus spp. (dossuarius?)	67				7			1
Testudinella patina	68							
Bosminopsis deitersi	69							
Calanoida copepodid	71	325	284	70701	3096	3411	19918	16289
Calanoida adult (Acartia tonsa)	72		99	65698	1399	4447	17382	14838
Chironomidae	80							
Euchlanis spp.	83							
Rotaria spp.	85							
Brachionus caudatus	93							
	X̄	328	131	2133	296	560	1839	

Table A59. (Continued)

Species	Species Number	Pans 6	Pans 7	Pans 8	Pans x̄	Marshes 110	Marshes 107	Marshes 104	Marshes 204	Marshes x̄
Synchaeta spp.	1	65576	60921	93982	73493	248163	22100	145507	87506	125819
Copepoda nauplii	2	13382	24131	48914	28809	14647	14583	52893	33062	28796
Notholca acuminata	7	62			21	41	48			22
Notholca marina	8	173		275	149	22406	482	2222	303	6353
Notholca labis	9	12	27	3847	1296	617	448	181		312
Notholca bipalium	10					44	73			29
Keratella americana	11								3640	910
Keratella quadrata	12		298		99					
Keratella cochlearis	13									
Kellicotia bostoniensis	14	37			12					
Lecane spp.	17						24			6
Brachionus spp.	18						12			3
Trichocerca capucina	19	12			4					
Cladocera	21					22				6
Notholca striata	25			137	46					
Cirripedia nauplii	26	17	106	137	87		16			4
Ceriodaphnia spp.	29							30		8
Asplanchna spp.	30			2610	870					
Notholca spp.	31		27		9					
Harpacticoida	33							40		10
Cyclopoida copepodid	34		160	137	99	1206	5	353		391
Cyclopoida adult	36		53		18	788		242		257
Trichocerca spp.	38						12			3
Keratella valga	39							181	273	114
Brachionus havanaensis	43									
Brachionus angularis	53									
Conochilus spp. (*dossuarius*?)	67									
Testudinella patina	68							40		10
Bosminopsis deitersi	69									
Calanoida copepodid	71	11532	6950	4946	7810	4650	2797	9042	104645	[illegible]
Calanoida adult (*Acartia tonsa*)	72	6132	11348	7282	8254	1442	1553	3252	50806	[illegible]
Chironomidae	80								152	38
Euchlanis spp.	83									
Rotaria spp.	85									
Brachionus caudatus	93									
	x̄	1065	1143	1783		3231	463	2351	3081	

were unique to the marsh stations: Keratella americana, Brachionus spp., Cladocera, Ceriodaphnia spp., Trichocerca spp., Keratella valga, Testudinella patina, and Chironomidae. Four taxa were highly abundant. Four taxa including 2 new taxa were abundant, and 11 taxa including 9 new taxa were moderately abundant. The remaining taxa were, respectively, either common (11 taxa including 7 new taxa) or rare (13 taxa including 7 new taxa).

B. Recurrent Groups by Season of Microzooplankton: Distributions, Statistics, and Characterizations

1. Spring Groups

Recurrent groups for microzooplankton during sp_ing months (March, April, and May) are given in Figure 3. Two groups were formed. Group I is made up of six taxa with three associate members. Group II is composed of two members. Members of Groups I and II are rather common in terms of frequency of occurrences.

Group I was found together in 11 samples. These samples were found primarily (64%) at lake stations and to a lesser extent in the marshes and passes (18% each). Group II was found together in 12 and 8 samples; it occurred equally (42%) at lake and pass stations and to a lesser extent (17%) in the marshes.

There was significant concordance ($P < 0.01$) within taxa of Group I, which indicates the following dominance relationships: Copepoda nauplii > B. angularis > Synchaeta spp. > Calanoida copepodid > Cyclopoida copepodid > and Calanoida adult. For both Groups I and II, concordance within taxa was not significant (Table 5).

Selected statistics and characterizations for the spring microzooplankton groups are given in Table 510.

Taxa of Group I are frequent members of the microzooplankton community; they are present at least >68% of the time. However, Copepoda nauplii dominated 92% of the samples; Synchaeta spp. dominated 26% of the samples; and Synchaeta spp. was dominant 8% of the time. All other taxa and the associate members were either not dominant or rarely so. Brachionus angularis and Copepoda nauplii were the most abundant forms by one to two orders of magnitude (10^5 compared to 10^4 and 10^3 inds/m^3). These two taxa were more highly dispersed than the other taxa ($k \simeq 10^5$ compared to 10^4). Calanoida adults (probably Acartia tonsa), Cirripedia nauplii, and Harpacticoids were more strongly aggregated ($k \sim 10^3$). Group I and its associates are dominated by brackish water forms.

Groups II and its associates were relatively frequent components of the microzooplankton; they were present in at least 26% of the samples. However, they were seldom dominant. Mean densities for Cirripedia nauplii and Mytilina mucronata are $\sim 10^2$ and $\sim 10^3$ inds/m^3 respectively, and for the rotifer, Filinia pejleri, is $\sim 10^4$ inds/m^3. All taxa showed a pattern of aggregation.

2. Summer Groups

Recurrent groups for microzooplankton during summer months (June, July, August, and September) are shown in Figure 3. Three groups were formed. Group I has 10 members and one associate. Groups II and III each contain two members; there is one associate for Group II and none for Group III.

Table A510. Selected Statistics for Microzooplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for Spring (March, April, and May) of 1978†

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
<u>GROUP I</u>										
Brachionus angularis	31	3	123990	76655	2	2616	4	0.11	1.5×10^6	FBW
Calanoida adult	27	0	3014	1052	8	880	5	0.17	1.1×10^4	--
Calanoida copepodid	34	1	15482	2732	5	11712	2	0.25	1.5×10^4	--
Copepoda nauplii	37	35	140064	24030	1	84160	1	UND*	1.3×10^5	--
Cyclopoida copepodid	26	0	3103	1743	7	586	6	0.10	3.1×10^4	--
Synchaeta spp.	32	10	58410	24452	3	4428	3	0.14	3.2×10^5	BW
<u>ASSOCIATES</u>										
Brachionus plicatilis	14	0	17341	13988	4	0	---	0.04	3.6×10^5	BW
Harpacticoida	15	0	438	180	16	0	---	0.06	2.3×10^3	Benthic
Notholca marina	10	0	653	443	14	0	---	0.04	9.6×10^4	BW
<u>GROUP II</u>										
Cirripedia nauplii	21	0	634	190	15	96	7	0.10	1.8×10^3	BW
Pilinia pejleri	16	2	11537	5193	6	0	---	0.04	7.5×10^4	FBW
<u>ASSOCIATE</u>										
Mytilina mucronata	10	0	2038	1072	9	0	---	0.03	1.8×10^4	FW

†See Materials and Methods section in text.

*Undefined.

Group I was found together in 11 samples. It was found mostly (45%) at lake stations, but it also occurred in the marsh (36%) and passes (18%). Group II was found together in 14 samples. It was found equally (43%) at marsh and lake stations. Group III was found together in 7 samples. Over 70% of this group's occurrences was at marsh stations.

There was significant concordance ($P < 0.01$) within taxa and samples for Groups I and II (Table 5).

Selected statistics and characteristics for the summer microzooplankton groups are given in Table A511.

Taxa of Group I are frequent members of the microzooplankton community during the summer; they are present at least 50% of the time (Cirripedia nauplii). The associate member, the harpacticoid copepod, was present in 36% of the samples. Copepoda nauplii dominated other members of Group I; it was dominant in 32 of the 52 samples. Copepoda nauplii, *B. angularis*, and *F. pejleri* mean abundances (10^5 inds/m^3) are one order of magnitude larger than the other taxa. Calanoid nauplii were more aggregated and more dispersed than the other taxa.

Group II and III were relative frequent components of the microzooplankton ($\geq$13% frequency), but their taxa were never very dominant (<6 out of 52 samples). However, the mean abundance of *Conochilus* spp. was ranked first compared to the other taxa; the median values are probably a more accurate indication of abundances because they are not affected by skewed data as means are. The k-value for Cyclopoida adult indicates less aggregation than many of the other taxa.

Table A511. Selected Statistics for Microzooplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for Summer (June, July, August, and September) of 1978[†]

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
GROUP I										
Brachionus angularis	46	10	142273	58550	4	11334	2	0.17	1.2×10^6	FBW
Brachionus plicatilis	47	8	76215	23173	7	8316	4	0.20	3.6×10^5	BW
Calanoida adult	43	1	37671	9877	9	7658	5	0.15	1.3×10^5	
Calanoida copepodid	46	4	77170	20242	6	10892	3	0.16	2.7×10^5	
Cirripedia nauplii	26	0	1265	409	30	4	11	0.07	6.7×10^3	BW
Copepoda nauplii	49	32	401287	96923	2	100826	1	0.19	1.2×10^6	
Cyclopoida copepodid	35	2	24371	12508	11	1450	8	0.09	3.3×10^5	
Filinia pejleri	40	7	126367	42495	5	7436	6	0.10	7.3×10^5	FBW
Synchaeta spp.	32	1	10784	4847	16	536	9	0.08	1.1×10^5	BW
Texadina sphinctosoma	38	0	14609	4099	14	1686	7	0.11	5.9×10^4	Benthic
ASSOCIATES										
Harpacticoida	19	0	1876	923	25	0	---	0.04	2.3×10^4	FW
GROUP II										
Conochilus sp. (dossuarius ?)	25	6	734774	453262	1	0	---	0.04	1.4×10^7	FW
Cyclopoida adult	17	0	18300	17539	13	0	---	0.03	8.6×10^5	
ASSOCIATES										
Trichocerca			13406	8278	15	20	10	0.06	2.6×10^5	FW
GROUP III										
Bosminopsis deitersi	17	6	161944	113094	3	0	---	0.02	4.0×10^6	FW
Daphnidae	7	0		21829	10	0	---	0.01	8.0×10^5	FW

[†] See Materials and Methods section in text.

3. Fall Groups

Recurrent groups for microzooplankton during fall months (October and November) are shown in Figure 3. Two groups were formed. Group I is composed of five members with three associates. There are two taxa in Group II.

Group I was found together in seven samples; it was found primarily (43% of the time) at pass stations and to a lesser extent in the lake and marshes (29% each). Group II was found together in eight samples; it occurred four times at lake stations, twice in the tidal passes, and twice at marsh stations. There was significant concordance within taxa and samples of Group I (Table 5).

Selected statistics and characterizations of the fall microzooplankton groups are given in Table A512.

Taxa of Group I and its associates are frequent members of the microzooplankton community and are present in at least 41% of the samples. Adult Copepoda nauplii dominated the other forms of Group I, 36% and 82%, respectively, of the time. These two forms were also the most abundant; their respective means were 2nd and 1st rank. Cyclopoida adult and Harpacticoida were apparently more randomly dispersed than most of the other taxa. Taxa are predominately brackish water forms.

Taxa of Group II were present at least 45% of the time but were never dominant forms.

4. Winter Groups

Recurrent groups for microzooplankton during winter months (December, January, and February) are given in Figure 3. Two groups were formed. Group I is composed of five taxa with two associate members. Group II is composed of two taxa.

Table A512. Selected Statistics for Microzooplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for Fall (October and November) of 1978†

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
GROUP I										
Calanoida adult	22	8	565499	397954	1	4960	2	0.21	6.2×10^6	
Calanoida copepodid	21	2	11507	3894	3	4576	3	0.29	2.9×10^4	
Copepoda nauplii	21	18	69869	20902	2	33760	1	0.25	1.4×10^5	
Harpacticoida	9	0	149	63	11	0	---	0.07	5.9×10^2	FW
Texadina sphinctosoma	9	0	212	108	10	0	---	0.06	1.2×10^3	TPB
ASSOCIATE										
Cyclopoida adult	10	1	234	101	9	0	---	0.08	9.7×10^2	
Cyclopoida copepodid	12	0	881	387	6	52	6	0.08	3.7×10^3	
Synchaeta spp.	15	2	2033	741	5	158	5	0.12	5.9×10^3	BW
GROUP II										
Brachionus angularis	14	0	3221	1967	4	214	4	0.10	2.6×10^4	FBW
Cirripedia nauplii	10	0	312	157	8	0	---	0.07	1.7×10^3	BW

† See Materials and Methods section in text.

Group I was found together in 14 samples; it occurred mainly (50%) at lake stations but was also strongly evident (36%) at marsh stations. Group II was found together in six samples; it occurred 50% of the time at lake stations, 33% in the marshes, and 17% in the passes.

There was significant concordance within taxa and samples of Group I (Table 5). Selected statistics and characterizations of the winter microzooplankton groups are given in Table A513.

Taxa of Group I and its associates were present at least 33% of the time. However, *Synchaeta* spp. dominated in 19 of the 27 samples; Copepoda nauplii dominated in 9 of the 27 samples. The rotifer, *Synchaeta* spp., and Copepoda forms were the most abundant forms of the winter taxa. *Synchaeta* spp. was highly dispersed; *Notholca marina* was more aggregated (k $\sim 10^5$ compared to 10^4). Brackish water forms dominate this group.

Table A513. Selected Statistics of Microzooplankton Taxa from Lake Pontchartrain Organized by Recurrent Groups (Fager 1957) for Winter (December, January, and February) of 1978[†]

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
GROUP I										
Calanoida adult	24	1	19705	7524	4	4958	4	0.28	6.3×10^4	
Calanoida copepodid	25	3	27382	10933	3	10194	3	UND*	9.6×10^4	
Copepoda nauplii	27	9	44226	9225	2	33712	2	UND*	4.2×10^4	
Notholca marina	16	0	5024	4060	5	136	5	0.09	7.2×10^4	BW
Synchaeta spp.	27	19	143259	40126	1	54262	1	UND*	2.4×10^5	BW
ASSOCIATES										
Cirripedia nauplii	9	0	99	43	12	0	---	0.06	4.1×10^2	BW
Notholca labis	11	0	602	364	6	0	---	0.0[illegible]	4.8×10^3	FBW
GROUP II										
Cyclopoida adult	7	0	201	133	10	0	---	0.04	1.9×10^3	
Cyclopoida copepodid	12	0	413	172	7	0	---	0.08	1.6×10^3	

[†]See Materials and Methods section in text.

*Undefined.

APPENDIX 6

MACROZOOPLANKTON

A. Taxa, Distributions, and Abundances by Season

B. Recurrent Groups by Season: Distributions, Statistics, and Characterizations

A. Taxa, Distributions, and Abundances by Season

1. Spring

Abridged macrozooplankton taxa and abundance categories for spring months grouped into lake, pass, and marsh stations are given in Table A61; detailed data per taxa per station are given in Table A62.

During the spring of 1978, 15 macrozooplankton taxa were identified from 34 samples. Eleven taxa were identified from the lake samples, 6 taxa from the tidal pass samples, and 13 taxa from the marsh samples. Two taxa, Cyclopoida copepodid and crustacean larvae, were found only at lake stations. Three taxa, Harpacticoida spp., Isopoda sp., and *Chaoborus* larvae were found only at marsh stations.

Eurytemora affinis, *Acartia tonsa*, Copepoda nauplii, shrimp mysis, crab zoea (*Rhithropanopeus harrisii*), Cladocera spp., and *Argulus* sp. were found throughout the lake. *A. tonsa* was moderately abundant ($>10^1$ to $<10^2$ inds/m^3) at the lake stations. Five taxa, *E. affinis*, *M. edax*, crab zoea, Cladocera spp., and *Chaoborus* sp., were moderately abundant at the marsh stations. Four taxa including one new taxa, Copepoda nauplii, were common ($10^0 < n \leq 10^1$ inds/m^3).

Twelve taxa including 8 new taxa (Cyclopoida copepodid, Amphipoda spp., shrimp mysis, crustacean larvae, *Argulus* sp., Harpacticoida spp., Isopoda spp., and decapod megalop) were rare in abundance ($n \leq 10^0$ inds/m^3).

2. Summer

Abridged macrozooplankton taxa and abundance categories for summer months are given in Table A63 (detailed data per taxa per stations are given in Table A64).

Table A61. Macrozooplankton Abundance Categories per m^3 Combined for Stations in the Lake, City Shore, Passes, and Marshes During Spring (March, April, and May) 1978 in Lake Pontchartrain, LA, Environs

Abundance Category	Lake	City	Passes	Marshes	New Taxa*
$10^1 < n \leq 10^2$ Moderately Abundant	Acartia tonsa (3) (1)			Eurytemora affinis (2) Mesocyclops edax (5) Crab Zoea (15) Cladocera spp. (16) Chaoborus sp. (17) (5)	6
$10^0 < n \leq 10^1$ Common	Eurytemora affinis (2) Copepoda nauplii (4) Crab Zoea (15) (3)		Acartia tonsa (3) Copepoda nauplii (4) Crab Zoea (15) (3)	Acartia tonsa (3) (1)	1
$n \leq 1$ Rare	Mesocyclops edax (5) Cyclopoid copepodid (6) Amphipoda spp. (8) Shrimp mysis (9) Cladocera spp. (16) Crustacean larvae (18) Argulus sp. (21) (7)		Eurytemora affinis (2) Shrimp mysis (9) Cladocera spp. (16) Argulus spp. (21) (4)	Harpacticoida spp. (1) Copepoda nauplii (4) Amphipoda spp. (8) Shrimp mysis (9) Isopoda spp. (14) Decapoda megalops (20) Argulus sp. (21) (7)	8
Unique Taxa	Cyclopoid copepodid (6) Crustacean larvae (18) (2)			Harpacticoida spp. (1) Isopoda spp. (14) Chaoborus sp. (17) (3)	5
Total Taxa	11		7	13	(15)

*New taxa not present in previous abundance categories.

Table A62. Abundances of Macrozooplankton Taxa per 100 m^3 During Spring (March, April, and May) of 1978 in Lake Pontchartrain, LA, By Individual Stations

Spring Taxa	Lake West 1	Lake West 10	Lake Mid 12	Lake Mid 4	Lake East 5	Lake East 105	Lake $\bar{X}$	Passes 6	Passes 7	Passes 8	Passes $\bar{X}$	Marshes 110	Marshes 107	Marshes 104	Marshes 204	Marshes $\bar{X}$
1. *Harpacticoida* spp.													49			16
2. *Eurytemora affinis*	86	15	531	2866	73	22	599	51	103	18	57	32	278	5655	87	1513
3. *Acartia tonsa*	63	20	13272	1051	584	66	209	574	1355	57	662	72	392	264	40	192
4. Copepod nauplii		70	17	116	493		116	51	694		248		53		9	15
5. *Mesocyclops edax*	10	100	80		50	20	43					20		6710	7830	3640
6. Cyclopoid copepodid				33			6									
8. Amphipoda spp.	2						<1					14	49		84	37
9. Shrimp mysis		10	14	8	20		9	49	22		24	28	15		24	17
14. Isopoda spp.													15			4
15. Crab Zoea (*Rhithropanopeus harrisii*)	32	890	733	243	566	50	436	364	1187	333	628	1979	4647	67	62	[illegible]
16. Cladocera spp.		18		11	52		14	17	15		11	8		6081	918	1752
17. Chaoborus larvae															14840	3710
18. Crustacea larvae		2					<1									
20. Decapoda megalops														8		2
21. *Argulus* spp.			9				2		49		16	15	15		9	14
22. Insecta												249	31		19	75
$\bar{X}$	12	70	916	271	121	10	233	69	214	26	103	152	347	1174	1495	[illegible]
Number of taxa	5	8	7	7	7	4	11	6	7	3	7	9	10	6	11	14

Table A63. Macrozooplankton Abundance Categories per m^3 Combined for Stations in the Lake, City Shore, Passes, and Marshes During Summer (June, July, August, and September) 1978 in Lake Pontchartrain, LA, Environs

Abundance Category	Lake	City	Passes	Marshes	New Taxa*
$10^2 < n \leq 10^3$ Abundant				Cladocera spp. (16) (1)	1
$10^1 < n \leq 10^2$ Moderately Abundant	Crab Zoea (15) (1)		Crab Zoea (15) (1)	Copepoda nauplii (4) *Mesocyclops edax* (5) Crab Zoea (15) *Diaptomus* sp. (19) (4)	4
$10^0 < n \leq 10^1$ Common	Harpacticoida spp. (1) *Acartia tonsa* (3) Copepoda nauplii (4) *Argulus* sp. (21) (4)	*Acartia tonsa* (3) Shrimp mysis (9) Crab Zoea (15) (3)	*Acartia tonsa* (3) (1)	*Acartia tonsa* (3) (1)	3
$n \leq 1$ Rare	*Eurytemora affinis* (2) *Mesocyclops edax* (5) Shrimp mysis (9) Isopoda spp. (14) Cladocera spp. (16) *Diaptomus* sp. (19) (6)	Amphipoda spp. (8) Cladocera spp. (16) *Argulus* sp. (21) (3)	Harpacticoida spp. (1) *Eurytemora affinis* (2) Copepoda nauplii (4) Cyclopoida copepodid (6) Amphipoda spp. (8) Shrimp mysis (9) Isopoda spp. (14) Cladocera spp. (16) *Argulus* sp. (21) (9)	Harpacticoida spp. (1) *Eurytemora affinis* (2) Amphipoda spp. (8) Shrimp mysis (9) Isopoda spp. (14) *Argulus* sp. (21) Polychaeta (23) (7)	5
Unique Taxa			Cyclopoida copepodid (6) (1)	Polychaeta (23) (1)	2
Total Taxa	11	6	[illegible]	13	(14)

*New taxa not present in previous abundance categories.

Table A64. Abundances of Macrozooplankton Taxa per 100 m^3 During Summer (June, July, August, and September) of 1978 in Lake Pontchartrain, LA, By Individual Stations

Summer Taxa	Lake							City				Passes				Marshes				
	West		Mid		East															
	1	10	12	4	5	105	$\bar{x}$	212	312	412	$\bar{x}$	6	7	8	$\bar{x}$	110	107	104	204	$\bar{x}$
1. <u>Harpacticoida</u> spp.		1220					203						7		2			3	5	2
2. <u>Eurytemora affinis</u>	53						9					11			4	161				40
3. <u>Acartia tonsa</u>	516	86	45	557	570	275	342	97	244	229	190	330	21	60	137	29	683	6	16	184
4. Copepoda nauplii		2862		56	17	341	546					143	7	84	78	330	36	4541		1227
5. <u>Mesocyclops edax</u>	260				20		47										10	2874	5957	2210
6. Cyclopoid copepodid												16			5					
8. Amphipoda spp.								4		115	39			3	1			11	3	4
9. Shrimp mysis						30	5			435	145	5			2	9	70			20
14. Isopoda spp.	23	2	1	3	3	4	6					5		4	3		73	49	109	58
15. Crab Zoea (<u>Rhithropanopeus harrisii</u>)	4318	13791	147	320	772	541	3315	131	255	827	404	2481	1847	206	1511	389	2610	3751	2107	2214
16. Cladocera spp.	116			18	36		28			115	38	16	23		13	133	78	96005	17079	28324
19. <u>Diaptomus</u> sp.					8		1									19		8249	22101	7592
21. <u>Argulus</u> sp.	197	1003	32	21	34	8	217	69	31	8	36	57	65	34	52	60	23	22	9	28
22. Insecta			9	3	11		4	4			1			18	6	199		5	29	58
23. Polychaeta																			3	1
$\bar{x}$	366	1264	16	65	98	80	315	20	35	115	57	204	131	27	121	89	239	7701	3161	2794
Number of Taxa	7	6	5	7	9	6	12	5	3	6	7	9	6	7	12	9	8	11	11	14

During the summer of 1978, 14 taxa were identified from 55 samples. Eleven taxa were identified from the lake samples, 6 taxa from city samples, 12 from the tidal pass samples, and 13 from the marsh samples. One taxon, Cyclopoida copepodid, was found only at the tidal pass stations; and one taxon, Polychaeta,was found only at the marsh stations.

Acartia tonsa, shrimp mysis, crab zoea (*Rhithropanopeus harrisii*), Cladocera spp., and *Argulus* sp. were the four most frequent occurring taxa and were found at all the stations. Cladocera spp. was abundant ($>10^2$ to $<10^3$ inds/m^3) at the Lacombe marsh stations (S104 and S204). Four taxa, Copepoda nauplii, *Mesocyclops edax*, crab zoea, and *Diaptomus* sp.,were moderately abundant.

Six taxa including 4 new taxa, Harpacticoida spp., *Acartia tonsa*, shrimp mysis, and *Argulus* sp., were common in abundance ($>10^0$ to $<10^1$ inds/m^3). Thirteen taxa including 5 new taxa, *Eurytemora affinis*, Isopoda spp., Amphipoda spp., Cyclopoida copepodid, and Polychaeta, were rare ($<10^0$ inds/m^3).

3. Fall

Abridged macrozooplankton taxa and abundance categories for fall months are given in Table A65 (detailed data per taxa per station are given in Table A66).

During the fall of 1978, 10 macrozooplankton taxa were identified from 28 samples. Eight taxa were identified from the lake samples; 9 taxa from city samples; 7 taxa, from the tidal passes; and 9 taxa, from the marsh samples (Table 29). One taxa, *Diaptomus* sp., was found only at the city station 212. *Acartia tonsa* and Copepoda nauplii occurred more frequently than the other taxa. *A. tonsa* and Copepoda nauplii abundances were common ($>10^0$ to $<10^1$ inds/m^3). Nine taxa including 8 new taxa,

Table A65. Macrozooplankton Abundance Categories per m^3 Combined for Stations in the Lake, City Shore, Passes, and Marshes During Fall (October and November) 1978 in Lake Pontchartrain, LA, Environs

Abundance Category	Lake	City	Passes	Marshes	New Taxa*
$10^0 < n \leq 10^1$ Common	*Acartia tonsa* (3) Copepoda nauplii (4) (2)	*Acartia tonsa* (3) Copepoda nauplii (4) (2)	*Acartia tonsa* (3) (1)	*Acartia tonsa* (3) (1)	2
$n \leq 1$ Rare	Harpacticoida spp. (1) *Eurytemora affinis* (2) Isopoda spp. (14) Crab Zoea (15) Cladocera spp. (16) *Argulus* sp. (21) (6)	Harpacticoida spp. (1) *Mesocyclops edax* (5) Isopoda spp. (14) Crab Zoea (15) Cladocera spp. (16) *Diaptomus* sp. (19) *Argulus* sp. (21) (7)	*Eurytemora affinis* (2) Copepoda nauplii (4) Isopoda spp. (14) Crab Zoea (15) Cladocera spp. (16) *Argulus* sp. (21) (6)	Harpacticoida spp. (1) *Eurytemora affinis* (2) Copepoda nauplii (4) *Mesocyclops edax* (5) Isopoda spp. (14) Crab Zoea (15) Cladocera spp. (16) *Argulus* sp. (21) (8)	8
Unique Taxa		*Diaptomus* sp. (19) (1)			1
Total Taxa	8	9	7	9	(10)

*New taxa not present in previous abundance categories.

Table A66. Abundances of Macrozooplankton Taxa per 100 m^3 During Fall (October and November) of 1978, in Lake Pontchartrain, LA, By Individual Stations

Fall Taxa	Lake							City				Passes				Marshes				
	West		Mid		East															
	1	10	12	4	5	105	$\bar{X}$	212	312	412	$\bar{X}$	6	7	8	$\bar{X}$	110	107	104	204	$\bar{X}$
1. *Harpacticoida* spp.				17	9		4			18	6					53			9	16
2. *Eurytemora affinis*				6	101	31	23						239		80		74		20	24
3. *Acartia tonsa*	40	14	722	283	79	37	196	314	19	17	116	8	346	48	134	748	111	59	35	238
4. Copepod nauplii	40		996	6	105		191	724		6	243		58		19	53			6	15
5. *Mesocyclops edax*										10	3								10	2
14. Isopoda spp.				12		21	6			36	12		40		13		184			46
15. Crab Zoea (*Rhithropanopeus harrisii*)	20		7		5		5	19	7	39	22	23			8	107	80			47
16. Cladocera spp.	20	14		25			10			11	4	8			3		90		70	40
19. *Diaptomus* sp.								17			6									
21. *Argulus* sp.	40	27	28		5		26	191	29	34	27		5	49	18				26	7
22. Insecta		14	7	12	50	45	21	19		30	16	15	5	10	10	53	63		111	57
$\bar{X}$	15	6	160	33	32	12	43	101	5	18	41	5	63	10	26	92	55	5	26	44
Number of Taxa	5	4	5	7	7	4	9	6	3	9	10	4	6	3	8	5	6	1	8	10

Harpacticoida, *Eurytemora affinis*, Isopoda spp., crab zoea, Cladocera spp., *Argulus* sp., Isopoda sp., and Copepoda nauplii were rare (<10^0 inds/m^3).

4. *Winter*

Abridged macrozooplankton taxa and abundance categories for winter months are given in Table A67 (detailed abundance data per taxa per station are given in Table A68). Twelve taxa were identified from 22 samples.

During winter of 1978, 10 taxa were identified from the lake stations, 4 taxa, from the city stations; 5 taxa, from the tidal pass stations; and 8 taxa, from the marsh stations. One taxa, Harpacticoida spp., was found only at the city stations; *Cyclops vernalis* and crab zoea (*Rhithropanopeus harrisii*) were present only at the lake stations. *Diaptomus* sp. was unique to the marsh stations. *Eurytemora affinis*, *Acartia tonsa*, and Copepoda nauplii were the three most frequently occurring taxa. *A. tonsa* and Copepoda nauplii were highly abundant (>10^3 inds/m^3) at the tidal pass stations and *A. tonsa* was also abundant (10^2 to <10^3 inds/m^3) at both the lake and marsh stations. *Eurytemora affinis* was abundant at the tidal pass stations and moderately abundant at the lake stations along with Copepoda nauplii. Three taxa abundances were common (>10^0 to <10^1 inds/m^3). Nine new taxa, Harpacticoida spp., *M. edax*, *Cyclops vernalis*, *Daphnidae* sp., Isopoda sp., crab zoea, Cladocera spp., Diaptomus sp., and *Argulus* sp., were rare (<10^0 inds/m^3).

Table A67. Macrozooplankton Abundance Categories per m^3 Combined for Stations in the Lake, City Shore, Passes, and Marshes During Winter (December, January, and February) 1978 in Lake Pontchartrain, LA, Environs

Abundance Category	Lake	City	Passes	Marshes	New Taxa*
$10^3 < n$ Highly Abundant			Acartia tonsa (3) Copepoda nauplii (4) (2)		2
$10^2 < n \leq 10^3$ Abundant	Acartia tonsa (3) (1)		Eurytemora affinis (2) (1)	Acartia tonsa (3) (1)	1
$10^1 < n \leq 10^2$ Moderately Abundant	Eurytemora affinis (2) Copepoda nauplii (4) (2)			Copepoda nauplii (4) (1)	0
$10^0 < n \leq 10^1$ Common		Acartia tonsa (3) Copepoda nauplii (4) (2)		Eurytemora affinis (2) (1)	0
$n \leq 1$ Rare	Mesocyclops edax (5) Cyclops vernalis (7) Daphnidae spp. (11) Isopoda spp. (14) Crab Zoea (15) Cladocera spp. (16) Argulus sp. (21) (7)	Harpacticoida spp. (1) Argulus sp. (21) (2)	Isopoda spp. (14) Cladocera spp. (16) (2)	Mesocyclops edax (5) Daphnidae sp. (11) Isopoda spp. (14) Cladocera spp. (16) Diaptomus sp. (19) (5)	9
Unique Taxa	Cyclops vernalis (7) Crab Zoea (15) (2)	Harpacticoida spp. (1) (1)		Diaptomus sp. (19) (2)	4
Total Taxa	10	4	5	8	(12)

*New taxa not present in previous abundance categories.

Table A68. Abundances of Macrozooplankton Taxa per 100 m^3 During Winter (December, January, and February) of 1978 in Lake Pontchartrain, LA, by Individual Stations

Winter Taxa	West 1	West 10	Lake Mid 12	Lake Mid 4	East 5	East 105	$\bar{X}$	City 212	City 312	City 412	City $\bar{X}$	Passes 6	Passes 7	Passes 8	Passes $\bar{X}$	Marshes 110	Marshes 107	Marshes 104	Marshes 204	Marshes $\bar{X}$
1. Harpacticoida spp.								5			2									
2. Eurytemora affinis	5999	909		1268	[illegible]	4106	2229					3101	874	10700	4892	751	1040	213	217	555
3. Acartia tonsa	16284	40	213	4360	64038	61166	24390	967	518		495	54753	208606	672659	312006	2513	98471		6469	26363
4. Copepoda nauplii	80		110		29700	48710	13100	1130	140		425	14430	34130	1336480	461680		53400			13350
5. Mesocyclops edax	53						9									28				7
7. [illegible] vernalis	31						14													
11. [illegible] sp.					[illegible]		49										347			87
14. Isopoda spp.	10						2					17			6	93	347			110
15. Crab Zoea (Rhithropanopeus harrisii)				136			23													
16. Cladocera spp.	60						10					26			9	75			72	37
19. Diaptomus sp.																28				7
21. Argulus sp.	5	2	8				3		5		2									
22. Insecta	24						4	10	5		5									
$\bar{X}$	1739	73	25	459	7315	8786	3621	162	51		71	5563	18739	155372	59891	268	11816	16	520	3155
Number of Taxa	9	3	3	3	4	3	11	4	4	0	5	5	3	3	5	6	5	1	3	8

B. Recurrent Groups by Season of Macrozooplankton: Distributions, Statistics, and Characterizations

1. Spring Groups

Recurrent groups, formed from those samples taken during spring months (March, April, and May), are given in Figure 4. Two groups were formed. Both Group I and Group II were composed of 2 taxa.

Group I, *A. tonsa* and crab zoea, was found together at 20 samples. It had 40% occurrence at the lake stations with 30% occurrence at both the pass and marsh stations. A Spearman rank correlation test on the rank of the taxa abundances of the 2 taxa over the 20 samples was not significant.

Group II, Cladocera spp. and *Eurytemora affinis*, occurred together at 12 stations. Group II was found 67% of the time at marsh stations and 17% both at lake and pass stations. A Spearman rank correlation test on taxa abundances within samples was significant at the 5% level, and suggests similarity between the species abundances and station locations. The first half of the stations, or those stations having maximum abundances, were in the Lacombe marsh area (S104 and S204).

Selected statistics and characterizations of the taxa for spring are given in Table A69. *A. tonsa* and crab zoea, (mostly *Rhithropanopeus harrisii*) are brackish water forms. They both occurred frequently during the spring, 85% and 76%, respectively. Crab zoea dominated 35% of the samples; *A. tonsa* dominated 29% of the samples.

Group II consisted mainly of freshwater species of Cladocerans and a brackish water species, *E. affinis*. *E. affinis* occurred in 56% of the samples and was the dominant taxa in 29% of the time. Cladocera spp. was the dominant taxa in 9% of the samples and occurred in 38% of the

Table A69. Selected Statistics for Macrozooplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for Spring (March, April, and May) of 1978†

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
Group I										
Acartia tonsa	29	10	25.25	18.74	1	0.64	2	0.49	389.58	BW
Crab Zoeae (*Rhithropanopeus harrisii*)	26	12	12.01	5.82	6	0.80	1	0.34	79.13	BW
Group II										
Cladocera spp.	13	3	12.10	6.69	5	0	---	0.16	103.66	FW
Eurytemora affinis	19	10	15.02	5.86	4	0.80	1	0.59	63.90	BW

†See Materials and Methods section in text.

samples. Cladocera spp. and E. affinis had a mean density of 10^1 inds/m^3. The k-values and variance:mean ratio for these 2 taxa possibly indicated aggregation of their populations.

2. Summer Groups

Recurrent groups formed from those samples during summer months (June, July, August, and September) are given in Figure 4. Two groups were formed. Group I is composed of 3 taxa, A. tonsa, Argulus sp., and crab zoea. Group II is made up of 2 taxa, Cladocera spp. and M. edax.

Group I was found together in 25 samples. Over half (64%) of the samples were from lake stations; 24% occurred at the tidal passes; and 12%, at the marsh stations. There was no significant relationship between abundances and station locations (Table 11).

Group II, Cladocera spp. and M. edax, occurred together at 11 stations. It was present in 64% of the samples from the marsh stations and in 36% from the lake stations. Group II did not occur in the tidal passes during the summer. A Spearman rank correlation test on the abundances of the two taxa within the 11 stations was not significant, which indicates that there is no relationship between abundances and station locations.

Selected statistics and characterizations of the taxa for summer groups are given in Table A610. A. tonsa, Argulus sp., and crab zoea are brackish water forms and were frequently present in the samples; for example, crab zoea was present 96% of the time; Argulus sp., 75%; and A. tonsa, 56%. Crab zoea was the dominant taxa (75%). The low k-values and variance:mean ratios indicate possible population aggregation for all 3 taxa.

Table A610. Selected Statistics for Macrozooplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for Summer (June, July, August, and September) of 1978†

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
Group I										
Acartia tonsa	31	9	2.38	0.70	3	0.16	3	0.36	11.18	BW
Argulus sp.	41	1	0.40	0.09	7	0.32	2	UND*	1.04	
Crab Zoeae (*Rhithropanopeus harrisii*)	53	41	11.28	2.32	1	2.70	1	1.63	25.75	BW
Group II										
Cladocera spp.	23	6	2.76	1.10	2	0	---	0.18	23.73	FW
Mesocyclops edax	11	0	0.36	0.17	8	0	---	0.08	4.49	FW

†See Materials and Methods section in text.

*Undefined.

Cladocera spp. and *M. edax* are mainly freshwater forms. Cladocera spp. was present in 42% of the samples and *M. edax* occurred in 20%. Cladocera spp. was the dominant taxa in 11% of the samples; *M. edax* was not dominant in any sample. The mean abundance for Cladocera spp. was about one order of magnitude greater than the mean density of *M. edax*. The k-values and variance:mean ratios of both taxa indicate slight aggregation (*M. edax*, $k < 10^0$ and variance:mean $> 10^0$; Cladocera spp., $k < 10^0$ and variance:mean $> 10^1$).

3. Fall Groups

Recurrent groups during fall months (October and November) are given in Figure 4. One group of two taxa was comprised of *A. tonsa* and *Argulus* sp. This group was found together in 10 samples and occurred 70% of the time at lake stations and 30% of the time in the passes. The taxa of this group did not occur together at any marsh station during fall. A Spearman rank correlation test showed no significance between the taxa abundances and station locations.

Selected statistics and characterizations are given in Table A611. *A. tonsa* was present in 82% of the samples and was the dominant taxa 43% of the time. *Argulus* sp. dominated in 25% of the samples and was a less frequent member of the group, being present in 43% of the samples. Mean abundance for *A. tonsa* was about 10 times greater than *Argulus* sp. Both taxa showed possible dispersion; their k-values are undefined and they have low variance:mean ratios (*A. tonsa* $< 10^1$ and *Argulus* sp. $< 10^0$).

4. Winter Groups

The recurrent group formed from those samples taken during winter months (December, January, and February) are given in Figure 4. One

Table A611. Selected Statistics for Macrozooplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for Fall (October and November) of 1978†

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
Group I							1	UND*	6.10	BW
Acartia tonsa	23	12	1.77	0.62	1	0.38	—	UND*	0.31	
Argulus sp.	12	7	0.16	0.04	6	0				

†See Materials and Methods section in text.

*Undefined.

group was formed with 2 taxa (*A. tonsa* and *Eurytemora affinis*) and an associate taxa (Copepoda nauplii).

Group I was found together in 13 samples. It occurred 46% of the time at the lake stations, 31% of the time at the tidal pass stations, and a 23% of the time at the marsh stations. A Spearman rank correlation test indicated a significant correlation ($P < 0.05$) between taxa abundances and station location. Those stations having the greatest abundances were the lake stations and tidal passes (43% each).

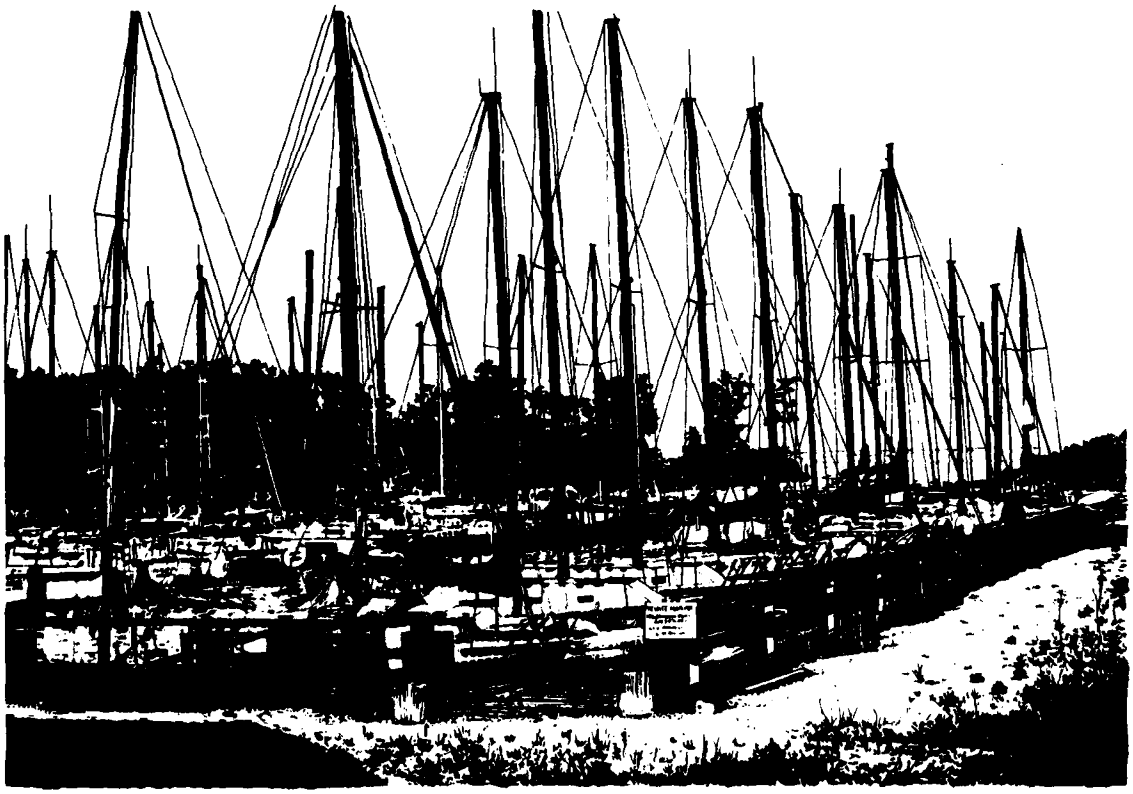
Selected statistics and characterizations are given in Table A612. *A. tonsa*, Copepoda nauplii, and *E. affinis* are brackish water taxa. *A. tonsa* was the most dominant taxa in the samples (91%) and occurred 95% of the time. Copepoda nauplii was present in 59% of the samples but was only dominant 9% of the time; *E. affinis* was present in 64% of the samples and was dominant in 22% of the samples. Mean density of Copepoda nauplii was about two times greater than *A. tonsa* mean density ($>10^3$ inds/m^3) and 62 times greater than *E. affinis* mean density ($>10^1$ inds/m^3). All three taxa exhibit aggregation with small k-values (*A. tonsa* k-value undefined) and large variance:mean ratios.

Table A612. Selected Statistics for Macrozooplankton Taxa from Lake Pontchartrain, LA, Organized by Recurrent Groups (Fager 1957) for Winter (December, January, and February) of 1978†

Taxa Groups	Frequency	Dominance	Mean	SE $\bar{X}$	Mean Rank	Median	Median Rank	K-Value	Variance/ Mean	Character
Group I										
Acartia tonsa	21	20	1476	1072	2	33.66	1	UND*	19483	BW
Eurytemora affinis	14	5	35.98	17.86	3	4.08	2	0.22	221.67	BW
ASSOCIATES										
Nauplii-copepoda	13	2	2254	2134	1	0.24	3	0.07	50513	BW

†See Materials and Methods section in text.

*Undefined.



Boat marina near Lewisburg, Louisiana

2-8

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